Appendix IX

Diesel PM Control Technologies

September 2000

INTRODUCTION

In preparation for the development of the Diesel RRP, ARB staff reviewed many products and technologies that were reported to reduce particulate emissions from diesel-fueled engines. The reviews consisted of two phases. In the first phase, ARB staff contacted manufacturers and collected basic information on the various diesel PM control technologies. Using this information, staff prepared short summaries of products that were reported to reduce diesel PM emissions. These "product summaries" are primarily based on information submitted by the control technology manufacturers, and they are intended to provide brief introductions of the various technologies. They are not intended to serve as comprehensive evaluations of the technologies. The product summaries are presented in Part A.

In the second phase of the technology review, staff worked with the Stationary Source Subcommittee to develop criteria for the evaluation of the various diesel PM control products. Specific criteria include commercial availability, emission reduction efficiency, costs, adverse impacts and other relevant factors. The evaluation criteria was then incorporated into a series of tables that have been completed for each of the diesel PM control products. Where multiple manufacturers provided information for similar technologies, a consolidated evaluation was prepared.

Because emission test information was deemed essential for a thorough evaluation, no evaluation was performed where the manufacturer did not provide adequate emission test data. Consequently, a number of the potentially viable technologies did not progress from the introductory first phase to the technical evaluations of the second phase. We are, however, continuing to collect and review information on these and other emerging diesel PM control technologies. The detailed technical evaluations are presented in Part B.

Note: Mention of specific products or trade names does not convey, and should not be interpreted as conveying, official ARB approval, endorsement, or recommendation. Unless otherwise noted, the ARB has not tested or evaluated any of the products to verify the claims of the manufacturer.

Part A: SUMMARY OF PRODUCTS THAT ARE REPORTED TO REDUCE PARTICULATE EMISSIONS FROM DIESEL-FUELED ENGINES

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PRODUCT SUMMARIES

Alternative Fuels

Product Name: Biodiesel
Manufacturers: NOPEC, Proctor and Gamble, Ag Environmental Products, Griffin Industries, West Central Soya, Columbus Food, and Pacific Biodiesel
Category: Alternative Fuel / Fuel Additive

Description:

The product is a liquid fuel for stationary, portable, and mobile compression ignition engines that is manufactured from various feedstocks, including soy and waste restaurant grease (yellow grease). The product can be used in pure form, or it can be mixed with standard diesel fuel. One common mixture, referred to as B20, includes 20 percent Biodiesel and 80 percent standard diesel. The product reduces the carbonaceous fraction of diesel particulate matter (PM) through improved in-cylinder combustion which can be attributed primarily to Biodiesel's high oxygen content (11 percent O2 by weight). According to the National Renewable Energy Laboratory (NREL), pure Biodiesel reduces PM emissions by an average of 55 percent, and B20 reduces PM emissions by an average of 18 percent. The product has also been tested in combination with original engine manufacturer (OEM) diesel oxidation catalysts.

The results of one series of federal test procedure (FTP) transient emission tests show that pure Biodiesel reduced total PM emissions by 28 percent to 49 percent, and that B20 reduced PM emissions by 4 percent to 15 percent. When tested with an OEM diesel oxidation catalyst over the FTP test cycle, pure Biodiesel reduced PM emissions by 48 percent to 60 percent, and B20 reduced PM emissions by 10 percent to 21

percent. However, the use of Biodiesel may increase oxide of nitrogen (NOx) emissions by up to 4 percent when using B20 and by up to 14 percent when using pure Biodiesel, although this effect varies depending on the feedstock. The NREL, the U.S. Department of Agriculture and the National Biodiesel Board are currently researching Biodiesel formulations which will minimize or eliminate these increases in NOx emissions.

The product is commercially available and has been tested in more than 50 urban bus fleets in the United States over the past six years. B20 can be used without changes to existing diesel engines or the fuel distribution infrastructure. However, the use of pure Biodiesel may require changing some engine seals and fuel lines in older engines. The cost of Biodiesel depends on the feedstock. In California where yellow grease is the principal feedstock, the cost of pure Biodiesel is currently between $2.00 to $3.00 per gallon (pre-tax), although costs continue to decline. According to the NREL, a B20 Biodiesel/California Air Resources Board (ARB) diesel blend could be produced for an additional $ 0.25 to $ 0.45 per gallon above the cost of ARB diesel. Because the heat content of pure Biodiesel is only 120,000 Btu/gal, fuel economy may degrade slightly (although test data show that the decrease in fuel economy is less than 4 percent for B20 blends). Biodiesel generally contains no sulfur or aromatics, and it can be blended with California's existing diesel fuel formulations. A Biodiesel blend must meet the American Society for Testing and Materials (ASTM) and ARB diesel specifications when used in motor vehicles.

Product Name: Fumigation Natural Gas/Diesel Bi-Fuel Retrofit Kit
Manufacturers: Innovative Technologies Group
Category: Alternative Fuel

Description:

The product reduces diesel PM, hydrocarbon (HC), carbon monoxide (CO), and NOx emissions from stationary, portable, and mobile diesel-fueled engines. Specifically, the product includes the components necessary to convert a diesel-fueled engine to run on a mixture of diesel and a variety of gaseous fuels, such as pipeline quality natural gas, liquefied natural gas, compressed natural gas, digester gas, etc… The supplemental gaseous fuel is introduced into the engine's charge air system via a fumigation process. According to the manufacturer, there is no loss of power, diesel fuel consumption can be reduced by 50 percent to 80 percent, and NOx emissions can be reduced by 20 percent to 60 percent. The results of one transient emission test show that, over the cold start CVS Federal Test Procedure, the product reduced diesel PM emissions by 28 percent, NOx emissions by 38 percent, HC emissions by 38 percent, and CO emissions by 6 percent.

ARB's Mobile Source Operations Division (MSOD) evaluated the product in response to an application for certification of an alternative fuel delivery system under Health and Safety Code 43004 and 43006. MSOD staff concluded that use of the product "will not adversely affect exhaust emissions…"

The product is commercially available, can be applied to new engines, and it can be retrofitted to existing engines. The product has been installed on more than 200 diesel-fueled engines, including stationary generators, trucks, busses and locomotives. The manufacturer states that the product life is consistent with that of other engine components. The initial product cost, which varies with engine size, is approximately $35/kW for engines larger than 500 kW. This cost includes both hardware and installation. The manufacturer provides a one-year warranty which includes full replacement of the engine if damage is caused by the bi-fuel process. The product can be used with the existing California diesel fuel formulations.

Engine Design and Modifications

Product Name: Cam Shaft Cylinder Reengineering Kit
Manufacturer: Clean Cam Technology Systems
Category: Engine Design

Description:

The product reduces diesel PM and NOx emissions from eleven models of two-stroke diesel-fueled engines manufactured by Detroit Diesel Corporation (DDC) before 1993. The product consists of specific engine retrofit components, including a proprietary cam shaft. The product reduces NOx emissions by increasing the volume of exhaust gas that remains in the combustion chamber after the power stroke. Within the combustion chamber, the residual exhaust gas absorbs heat and reduces the peak combustion temperature which results in lower NOx emissions. The injection timing can then be adjusted (i.e. advanced) to maximize diesel PM emission reductions, or it can be varied to achieve the desired balance of NOx vs. PM.

The manufacturer states that engines retrofitted with the product will have emissions of no greater than 1.0 gram per brake horsepower-hour (g/bhp-hr) of hydrocarbons, 8.5 g/bhp-hr of carbon monoxide, 5.8 g/bhp-hr of nitrogen oxides, and 0.16 g/bhp-hr of diesel PM. ARB staff have verified this claim, and the product has been certified through the ARB's Equipment and Process Certification Program. In addition, the results of two 8-mode steady-state source tests show that the product can reduce diesel PM emissions by up to 55 percent.

The product is commercially available and has been installed on over 125 portable and 400 mobile diesel-fueled engines. The manufacturer states that the product's useful

life is between 3,000 and 8,000 operating hours, and that the product life is consistent with the durability requirements for new nonroad engines. The initial product cost ranges from approximately $3,480 for a three cylinder engine to $15,680 for a sixteen cylinder engine. According to the manufacturer, there are no additional maintenance costs; however, the product can affect fuel economy. Although this effect can vary by engine, there may be a fuel penalty. The manufacturer provides a one-year / 3,000 engine hour warranty, and the product can be used with the existing California diesel fuel formulations.

Product Name: Diesel Emission Control System
Manufacturer: Clean Air Technology, a division of Applied Technology Solutions, Inc.
Category: Engine Modification

Description:

The product reduces diesel PM, HC, and NOx emissions from mobile, stationary, and portable diesel-fueled engines by introducing a combustion catalyst into the engine's air intake system. While the specific reactions are not known, the platinum oxide catalyst is believed to initiate combustion earlier such that the duration is longer which allows for more complete combustion. The manufacturer states that the product reduces both the elemental carbon and SOF of diesel PM, and that the overall diesel PM removal efficiency is between 30 percent and 60 percent. One steady-state source test shows that the product reduces diesel PM emissions by 48 percent, HC emissions by 65 percent, and NOx emissions by 51 percent.

MSOD evaluated an earlier version of the product in response to an application for exemption from the State's emission control system anti-tampering laws (Vehicle Code Section 27156). MSOD staff concluded that use of the product "will not have an adverse effect on exhaust emissions…"

The product is commercially available and has been installed on approximately 140 mobile diesel-fueled engines. The product has also been tested on at least one large portable diesel-fueled engine. The initial cost is $1,495, and it takes 2 hours to install. The maintenance cost, which consists of replacing the catalyst element, is $900 for every 1,200 hours of operation. The manufacturer warrants the product for 1,200 hours of operation. The product is also reported to improve fuel economy, and it can be used with the existing California diesel fuel formulations.

Product Name: ECOTIP Superstack Fuel Injectors
Manufacturer: Interstate Diesel
Category: Engine Design

Description:

The product reduces diesel PM emissions from stationary, portable, mobile, marine, and locomotive diesel-fueled engines manufactured by General Motors Electro-Motive Division (EMD) and DDC. The product consists of a fuel injector with a reduced sac volume and a more consistent fuel injection pressure, and it can be incorporated into either mechanical or electronic fuel injection systems. The product improves combustion and reduces diesel PM emissions by minimizing the amount of fuel that drips into the combustion chamber at the end of the chamber's fuel injection cycle. The manufacturer states that the overall diesel PM removal efficiency can be as high as 44 percent for EMD engines and as high as 7 percent for DDC engines.

The results of one 8-mode steady-state source test performed on a DDC engine equipped with the product show that it reduces diesel PM emissions by 7 percent, NOx emissions by 4 percent, and CO emissions by 19 percent, but that it increases HC emissions by 15 percent. (The ARB has not received emission test data for the EMD engines.) The product has also been tested with 2° injection timing retard, and the results of an 8-mode steady-state source test performed on a similar DDC engine show that the product can reduce diesel PM emissions by 3 percent, NOx emissions by 16 percent, CO emissions by 13 percent, and HC emissions by 1 percent.

The product is commercially available and has been installed on approximately 2,000 diesel-fueled engines. The manufacturer states that the product's useful life is typically between two and three years. For EMD engines, mechanical fuel injectors are available as OEM products and electronic fuel injectors are available as replacement products. For DDC engines, both mechanical and electronic fuel injectors are available as replacement products. The initial product cost for a DDC engine ranges from approximately $49 to $92 for each rebuilt fuel injector with core exchange, and between $250 and $300 for each new fuel injector. According to the manufacturer, there are no maintenance costs; however, fuel economy is reported to improve by 2 percent to 3 percent. The manufacturer provides a 12-month / 2,000 engine hour warranty, and the product can be used with the existing California diesel fuel formulations.

Product Name: IET 2000 Series Emission/Fuel Reduction System
Manufacturer: International Engine Technologies, Ltd.
Category: Engine Modification

Description:

The product reduces diesel PM emissions from mobile, stationary, and portable diesel-fueled engines by cleaning, heating, and mixing the fuel before it is delivered to the fuel injection system. The product includes: 1) a filter that cleans the fuel down to three to five microns; 2) a "homogenizer" that heats and mixes the fuel; and 3) a catalytic bed that imparts an electrical charge to the fuel. These components work together to improve fuel atomization and allow for more complete combustion. The manufacturer states that the product reduces both the elemental carbon and soluble organic fractions (SOF) of diesel PM, and that the overall diesel PM removal efficiency is between 20 percent and 50 percent. However, the ARB has not received emission test data that support this claim.

The product is commercially available and has been installed on eight mobile diesel-fueled engines. The manufacturer states that the product's useful life is 10 years or more. The initial cost varies with engine size and is $180 for 1.5 to 4 liter engines (catalytic bed only), $950 for 2 - 5 liter engines, $1,080 for 6 - 10 liter engines, and $1,250 for 11 - 15 liter engines. The product takes about one hour to install. The manufacturer states that fuel economy improves by 8 percent to 12 percent for engines with mechanical fuel injectors and by 3 percent to 5 percent for engines with electronic fuel injection. The manufacturer provides a one-year warranty, and the product can be used with the existing California diesel fuel formulations.

Fuel Borne Catalysts

Product Name: COMTEC Emission Control Device
Manufacturer: COMTEC Combustion Technologies, Inc.
Category: Fuel Borne Catalyst

Description:

The product is reported to reduce diesel PM, NOx, CO, and HC emissions from stationary, portable and mobile diesel-fueled engines. Specifically, the product is an in-line solid metal oxidation / fuel modification catalyst which changes the composition of diesel fuel immediately prior to its use in an engine. Subsequent combustion of the modified fuel results in a reduction of both the elemental carbon and SOF of diesel PM, as compared to untreated fuel. According to the manufacturer, the tin antimony-based catalyst converts some of the longer chain hydrocarbons into shorter chain hydrocarbons. Use of the product appears to increase the number of shorter chain hydrocarbons, particularly those in the C10 through C12 range, and slightly decrease the number of longer chain hydrocarbons. The manufacturer states that the product reduces diesel PM emissions by up to 40 percent, NOx emissions by up to 25 percent, CO emissions by up to 60 percent, and HC emissions by up to 60 percent. However, the ARB has not received emission test data that support this claim.

The product is commercially available and has been installed on several hundred diesel-fueled engines used primarily in marine vessels. These engines range in size from 150 horsepower to 10,000 horsepower. The product's useful life is 8,000 to 10,000 service hours and is guaranteed by the manufacturer. The initial product cost, which varies by engine size, ranges from $326 (US) for a 300 horsepower engine to $1,563 (US) for a 3,000 horsepower engine. The installation cost, which also varies by engine size, ranges from $150 to $500. The manufacturer reports an increase in fuel economy of between 3 percent and 7 percent. The product is covered by both a performance and a liability warranty, and it can be used with the existing California diesel fuel formulations.

Product Name: Platinum Plus® DFX diesel fuel combustion catalyst
Manufacturer: Clean Diesel Technologies, Inc.
Category: Fuel Additive

Description:

The product is a concentrated liquid fuel-borne catalyst (FBC) containing 4 to 8 parts per million (ppm) of fuel-soluble platinum and cerium metal that reduces diesel PM emissions from all stationary and portable diesel-fueled engine types. The product can be used alone or in conjunction with other control technologies such as diesel particulate filters (DPF) and diesel oxidation catalysts (DOC); and with NOx controls such as exhaust gas recirculation and injection timing retard. The FBC catalyzes the rate of soot oxidation and lowers the temperature at which soot oxidation takes place. The FBC is packaged as an aftermarket product, so fuel or bulk storage tanks can be dosed by the owner or operator. The product reduces the carbonaceous and SOF of diesel PM; however, the product appears most effective at reducing the dry carbonaceous fraction. The manufacturer states that the removal efficiency is dependent on the baseline emission level and chemical makeup of the diesel PM. Results from the heavy-duty engine transient FTP and a 13-mode steady-state source test shows that the product can reduce diesel PM emissions ranging from 15 percent to 30 percent for the FBC alone, 30 percent to 50 percent for a DOC+FBC, and 80 percent to 95 percent for a DPF+FBC combination.

The product is commercially available and has been applied to more than 60 heavy-duty trucks in the United States and to six large stationary diesel-fueled engines in Maine. FBC+DPF combinations have been applied to about 100 city buses in Taiwan. The initial cost to the end user varies based on the method of product distribution. Individually packaged products are expected to cost $0.10 to $0.12 per gallon of fuel treated; bulk treated fuel, or on-board additive is estimated to cost $0.05 to $0.10 per gallon of fuel treated. Additive cost is expected to be partially offset by fuel economy improvements in the range of 5 percent to 7 percent. Additional operation and maintenance costs are negligible for the FBC alone. If used with DOCs and DPFs, maintenance should be reduced owing to the reduced soot fouling and replenishment of catalytic activity with the FBC. The manufacturer states that the product's shelf life is about 24 months for individually packaged units and 12 to 18 months in fuel. The product works with diesel fuels containing up to 500 ppm sulfur at any operating temperature; when used with a DOC or catalyzed DPF, exhaust gas temperature should be maintained below 500 ˚C to avoid sulfation.

Other Exhaust Treatment Technologies

Product Name: NOxTECH Emission Control System
Manufacturer: NOxTECH, Inc.
Category: Exhaust Treatment

Description:

The product reduces diesel PM, CO, and HC emissions from stationary and portable diesel-fueled engines and turbines through non-catalytic oxidation (i.e. similar to an afterburner). When used with an aqueous urea injection system, the product also reduces emissions of NOx. The product consists of a muffler-size reactor where the exhaust gases are heated to a temperature of 1,400°F - 1,550°F by introducing fuel to the exhaust stream. Within this high temperature environment, diesel PM, CO, and HC emissions are oxidized. When a urea injection system is used, NOx emissions are reduced in a reaction with the aqueous urea.

The manufacturer states that the overall diesel PM removal efficiency can be as high as 90 percent. Test results from a steady-state source test of a 1.5 megawatt (MW) generator in Southern California demonstrated diesel PM removal efficiencies between 43 percent and 71 percent.

The product is commercially available and can be retrofitted to existing engines; however, it must be designed for each application. The product is currently being used on two stationary diesel-fueled engine-powered generators in Southern California. The initial costs are: $10 - $30 per horsepower for installations without the urea injection system or the heat exchanger; $15 - $37 per horsepower for installations with the urea injection system but without the heat exchanger; and $52 - $75 per horsepower for installations with both the urea injection system and the heat exchanger. The operating costs include a fuel penalty of approximately 5 percent to 8 percent, and when used, the cost of the aqueous urea is approximately $300 per ton of NOx reduced. The manufacturer guarantees that the product will be free from defects for a period of 12 months. The product can be used with the existing California diesel fuel formulations.

Product Name: SINOx (Selective Catalytic Reduction) System
Manufacturer: Siemens Westinghouse Power Corporation
Category: Exhaust Treatment

Description:

The product reduces diesel PM, NOx, and HC / air toxics (including odor, formaldehyde and polyaromatics) emissions from mobile, stationary, and portable diesel-fueled engines using a proprietary base metal catalyst designed specifically for diesel-fueled engines. According to the manufacturer, the product reduces the volatile organic fraction (VOF) of diesel PM and HC / air toxics emissions through catalytic oxidation. The product concurrently reduces NOx emissions through selective catalytic reduction using a reducing agent, such as a 32 percent aqueous urea solution, as an integrated control system. The manufacturer states that the product's overall diesel PM removal efficiency can be between 20 percent and 50 percent depending on the engine timing, the type of controls, and the uncontrolled emission rate. In addition, the product's VOF of diesel PM removal efficiency can be more than 60 percent, its HC / air toxics removal efficiency can be more than 90 percent, and its NOx removal efficiency can be over 90 percent in stationary and portable applications and 65 percent to 85 percent in heavy-duty truck applications. The product can be used through an exhaust temperature range of 350˚F to 1,020˚F, and it allows the injection timing to be adjusted (on non-certified engines) for maximum fuel efficiency which may result in further reductions of diesel PM and HC /air toxics and fuel savings. One transient driving cycle emission test of a 1999 certified Detroit Diesel Corporation Series 60 heavy-duty diesel-fueled truck engine shows that, over the hot start portions of the FTP, the product reduces the VOF of diesel PM by more than 60 percent, total diesel PM emissions by more than 20 percent (to less than 0.07 g/bhp-hr), HC emissions by 90 percent, and NOx emissions by 73 percent (to less than 1.0 g/bhp-hr). In addition, according to the manufacturer, a NOx emission rate of 0.5 g/bhp-hr was recently achieved on an engine equipped with both the product and a supplemental exhaust gas recirculation system.

The product is commercially available for engines rated at 200 to 10,000 horsepower or more, and it has been installed on 125 stationary, portable, and mobile diesel-fueled engines worldwide. Specific applications include: stationary and portable generator sets, pump stations, on-highway heavy-duty trucks, offroad construction equipment, marine vessels, locomotives, and others. The cost of the product depends on the degree of custom engineering required, the size of the engine, the operating conditions, and other variables such as production volume. For a 367 horsepower portable diesel-fueled engine, the initial cost would be approximately $7,000 depending on production volume and assuming minimal custom engineering. The operating cost would be approximately $300 per ton of NOx reduced (primarily for the aqueous urea), and the maintenance cost would be approximately $800 per year depending on run time and other variables. The manufacturer provides a one-year standard equipment

warranty for workmanship, parts and materials. The manufacturer also provides a process guarantee of up to 3-years / 20,000 service hours (whichever occurs first) for the emission reductions in stationary and portable applications. A 500,000 mile performance guarantee is provided for on-road applications. The product is resistant to fuel sulfur and can be used with the existing California diesel fuel formulations, as well as with high sulfur fuels such as bulk or crude oil used in coastal and ocean vessels.

Oxidation/Oxidation Catalysts

Product Name: CEM Catalytic Exhaust Muffler
Manufacturer: Johnson Matthey
Category: Exhaust Treatment

Description:

The product reduces diesel PM, CO, and HC emissions from mobile diesel engines through catalytic oxidation. Specifically, the product reduces the SOF of diesel PM by 50 percent to 60 percent. The product is certified under the U.S. Environmental Protection Agency's Urban Bus Retrofit/Rebuild Program, and the manufacturer guarantees that it will reduce overall diesel PM emissions by at least 25 percent. The manufacturer states that HC and CO emissions will be reduced by up to 50 percent or more. The results of one transient emission test show that, over the FTP, the product reduced diesel PM emissions by 51 percent, NOx emissions by 3 percent, HC emissions by 47 percent, and CO emissions by 40 percent.

MSOD evaluated the product in response to an application for exemption from the State's emission control system anti-tampering laws (Vehicle Code Section 27156). MSOD staff concluded that use of the product "…will not have any adverse effect on exhaust emissions of the engines for which the exemption is requested."

As is the case with most catalytic oxidation processes, the formation of sulfate particles increases at higher temperatures. While the product has been formulated to minimize the formation of sulfates, depending on the exhaust temperature and the sulfur content of the fuel, the increase in sulfate particles may offset the reduction in SOF emissions. This effect can be minimized by using diesel fuel with a very low sulfur content.

The product is commercially available for urban transit bus applications, and has been installed on several thousand transit buses in the United States. The product's initial cost depends on the engine / coach configuration and varies between $1,600 and $2,300. Installation takes between two and four hours and, according to the manufacturer, periodic maintenance is not normally required. For urban transit bus applications, the manufacturer provides an emission performance warranty for 150,000 miles and will replace defective parts for a period of 100,000 miles. The manufacturer

typically provides a one year unlimited mileage warranty for other applications. The product can be used with California's existing diesel fuel formulations.

Product Name: CleanDIESEL Converters
Manufacturer: Clean Air Systems
Category: Exhaust Treatment

Description:

The product reduces PM, CO, and HC emissions from stationary and portable diesel-fueled engines through catalytic oxidation. Specifically, the product reduces the SOF of diesel PM. The manufacturer states that the SOF removal efficiency can be as high as 80 percent at an exhaust temperature of 570˚F, and that the overall diesel PM removal efficiency should be between 25 percent and 43 percent. However, ARB has not received emission test data that support these claims.

As is the case with most catalytic oxidation processes, the formation of sulfate particles increases at higher temperatures. Depending on the exhaust temperature and the sulfur content of the fuel, the increase in sulfate particles may offset the reduction in SOF emissions. This effect can be minimized by using diesel fuel with a very low sulfur content.

The product is commercially available and has been installed on approximately 3,000 stationary, portable, and mobile diesel-fueled engines. The manufacturer states that the product's useful life should be approximately 10,000 engine hours. The initial cost ranges from $369 for a 150 cubic inch naturally aspirated engine to $4,079 for a 2,215 cubic inch turbocharged engine, and the product takes between one and six hours to install. The maintenance costs depend on the maintenance level of the engine: the catalyst may require periodic cleaning when installed on a poorly maintained engine or when the catalyst temperature does not regularly reach 570˚F. The product carries a one-year / 2,000 engine hour warranty and it can be used with the existing California diesel fuel formulations.

Product Name: DCC Diesel Catalytic Converter
Manufacturer: Johnson Matthey
Category: Exhaust Treatment

Description:

The product reduces diesel PM, CO, and HC emissions from mobile and portable diesel-fueled engines through catalytic oxidation. Specifically, the product reduces the SOF of diesel PM by 50 percent to 60 percent. The manufacturer states that the overall diesel PM removal efficiency ranges from 20 percent to 50 percent depending on the engine size and model year, exhaust temperature and flow rate, duty cycle, and condition of the engine. However, ARB has not received emission test data that support this claim.

As is the case with most catalytic oxidation processes, the formation of sulfate particles increases at higher temperatures. While the product incorporates sulfate suppressant technology, depending on the exhaust temperature and the sulfur content of the fuel, the increase in sulfate particles may offset the reduction in SOF emissions. This effect can be minimized by using diesel fuel with a very low sulfur content.

The product is commercially available for mobile diesel-fueled engines, and has been installed on more than three million engines worldwide. The initial product cost, which varies with engine size and emission reduction requirements, ranges from $500 to $3,000. The installation, operating, and maintenance costs also vary by application and engine size. The manufacturer typically provides a one year unlimited mileage warranty. The product can be used with the existing California diesel fuel formulations.

Product Name: Dieselytic SX Exhaust Gas Purifier
Manufacturer: Catalytic Exhaust Products Limited
Category: Exhaust Treatment

Description:

The product reduces diesel PM, CO, and HC emissions from stationary and portable diesel-fueled engines through catalytic oxidation. Specifically, the product reduces the SOF of diesel PM. The manufacturer states that the SOF removal efficiency ranges from 27 percent at an exhaust temperature of 275˚F to 91 percent at 600˚F. The overall diesel PM removal efficiency depends on the make-up of each engine's diesel PM emissions, but should be between 25 percent and 39 percent. One 8-mode steady-state source test shows that the product reduces diesel PM emissions by almost 16 percent, HC emissions by 39 percent, and CO emissions by 59 percent.

As is the case with most catalytic oxidation processes, the formation of sulfate particles increases at higher temperatures. Depending on the exhaust temperature and the sulfur content of the fuel, the increase in sulfate particles may offset the reduction in SOF emissions. This effect can be minimized by using diesel fuel with a very low sulfur content.

The product is commercially available and has been installed on approximately 15,000 portable and mobile diesel-fueled engines. Several units have also been installed in stationary applications. The manufacturer states that the product's useful life ranges from approximately 4,000 to 6,000 engine hours in heavy-duty applications to 8,000 to 10,000 engine hours in light-duty applications. The initial product cost, which varies with engine size, ranges from approximately $2,000 for a 250 horsepower engine to approximately $5,000 for a 550 horsepower engine. The manufacturer recommends cleaning the product every 6 months or 2,000 engine hours (whichever occurs first) when it is installed on newer engines, and every 3 months or 1,000 engine hours (whichever occurs first) when it is installed on older engines. The catalyst can be cleaned by the engine operator by: applying a compressed air stream to the face of the catalyst; heat treating the catalyst core; or soaking the catalyst in an appropriate solvent. The maintenance costs include the time and materials associated with the cleaning activity. The product carries a one-year / 2,000 engine hour warranty. The product can be used with the existing California diesel fuel formulations; however, the manufacturer recommends a maximum aromatic content of 18 percent.

Product Name: Flameless Thermal Oxidizer
Manufacturer: Thermatrix, Inc.
Category: Exhaust Treatment

Description:

The product reduces diesel PM, CO, and HC emissions from stationary and portable diesel-fueled engines and turbines through non-catalytic oxidation (i.e. similar to an afterburner). Exhaust gases are heated in a muffler-like enclosure where the organic gases are oxidized in the flameless, high temperature, environment. System temperature is maintained by introducing supplemental fuel to the exhaust stream which reacts within a proprietary inert ceramic matrix.

The product reduces the carbonaceous, soluble organic and sulfate fractions of diesel PM. The manufacturer states that the overall diesel PM removal efficiency should be greater than 90 percent, although emission test results will not be available until October 1999.

Although still under development, the product is expected to be available for commercial use within the next few years. The initial cost is projected at $3,000 for heavy-duty diesel engines. The operating costs consist primarily of the supplemental fuel use, which is between one and three percent. The product can be used with the existing California diesel fuel formulations.

Product Name: Nett D-series Diesel Purifier
Manufacturer: Nett Technologies, Inc.
Category: Exhaust Treatment

Description:

The product reduces diesel PM, CO, and HC emissions from stationary and portable diesel-fueled engines through catalytic oxidation. The catalyst formulation can be customized for specific engine applications, and can be designed to suppress the formation of sulfate particles. To enhance low temperature conversion, the product incorporates a zeolite trap which captures and temporarily stores hydrocarbon emissions, including the SOF of diesel PM. Upon reaching the catalysts' minimum conversion temperature of about 360˚F, the hydrocarbons are released from the zeolites and are oxidized by the catalyst. The zeolites can collect and store hydrocarbons for 15 to 30 minutes before becoming saturated. The manufacturer states that the product's SOF removal efficiency ranges from 40 percent at an exhaust temperature of 210˚F to 90 percent at 840˚F, and that the product's overall diesel PM removal efficiency can be as high as 10 percent to 50 percent. One 5-mode steady-state source test shows that the product reduces diesel PM emissions by 21 percent.

As is the case with most catalytic oxidation processes, the formation of sulfate particles increases at higher temperatures. While the product incorporates sulfate suppressants, depending on the exhaust temperature and the sulfur content of the fuel, the increase in sulfate particles may offset the reduction in SOF emissions. This effect can be minimized by using diesel fuel with a very low sulfur content.

The product is commercially available and has been installed on approximately 15,000 mobile, portable, and stationary diesel-fueled engines. The initial product cost, which varies with engine size, ranges from $4 to $20 per horsepower, and it takes approximately 1½ hours to install. The operating costs depend on the maintenance level of the engine as the catalyst may require periodic cleaning when installed on a poorly maintained engine. The manufacturer states that the product's useful life ranges from 15,000 to 25,000 engine hours depending on the condition of the engine, type of fuel and maintenance practices. The manufacturer provides a 2,000 hour limited warranty on mechanical durability. The product can be used with the existing California diesel fuel formulations.

Product Name: Nett Standard Diesel Purifier
Manufacturer: Nett Technologies, Inc.
Category: Exhaust Treatment

Description:

The product reduces diesel PM, CO, and HC emissions from stationary and portable diesel-fueled engines through catalytic oxidation. Specifically, the product reduces the SOF of diesel PM. The manufacturer states that the SOF removal efficiency ranges from zero percent at an exhaust temperature of 210°F to 90 percent at 840°F. The overall diesel PM removal efficiency is estimated at between 10 percent and 50 percent, but this has not been confirmed through emission testing.

As is the case with most catalytic oxidation processes, the formation of sulfate particles increases at higher temperatures. Depending on the exhaust temperature and the sulfur content of the fuel, the increase in sulfate particles may offset the reduction in SOF emissions. This effect can be minimized by using diesel fuel with a very low sulfur content.

The product is commercially available and has been installed on approximately 30,000 mobile, portable, and stationary diesel-fueled engines. The initial product cost, which varies with engine size, ranges from $3 to $14 per horsepower, and takes approximately 1½ hours to install. The operating costs depend on the maintenance level of the engine, because the catalyst may require periodic cleaning when installed on a poorly maintained engine. The manufacturer provides a 2,000 hour limited warranty on mechanical durability. The product can be used with the existing California diesel fuel formulations.

Product Name: PTX Oxidation Catalyst
Manufacturer: Engelhard Corporation
Category: Exhaust Treatment

Description:

The product reduces diesel PM, CO, and HC emissions from mobile, stationary, and portable diesel-fueled engines through catalytic oxidation. The product reduces both the carbonaceous fraction and the SOF of diesel PM. The manufacturer states that the SOF removal efficiency can be as high as 50 percent to 90 percent, and that the overall diesel PM removal efficiency can be as high as 25 percent to 50 percent. The results of one emission test of a bulldozer, which was tested over a specially designed transient cycle, show that the product reduces total diesel PM emissions by 24 percent.

As is the case with most catalytic oxidation processes, the formation of sulfate particles increases at higher temperatures. Depending on the exhaust temperature and the sulfur content of the fuel, the increase in sulfate particles may offset the reduction in SOF emissions. This effect can be minimized by using diesel fuel with a very low sulfur content.

The product is commercially available and has been installed on several thousand mostly-mobile diesel-fueled engines. The manufacturer states that the product's useful life is consistent with the life of the associated diesel-fueled engine, and they recommend replacing the catalyst at the time an engine is rebuilt. The product's initial cost varies between $5 and $15 per horsepower. According to the manufacturer, periodic maintenance is not normally required. The product carries a mechanical durability warranty of between one and two years, depending on the application, and the product can be used with California's existing diesel fuel formulations.

Particulate Filters

Product Name: 3M Diesel Particulate Filter Cartridges
Manufacturer: Minnesota Mining and Manufacturing (3M)
Category: Exhaust Treatment

Description:

3M manufactures several ceramic fiber-based cartridges that are one component of particulate filter systems assembled by other companies. The cartridges can reduce the carbonaceous and soluble organic fractions of diesel PM by collecting the contaminants on ceramic fibers. They can be regenerated either electrically via internal heating elements or by external methods, such as fuel burners, fuel additives,

catalysts, and microwaves. The manufacturer states that the overall diesel PM removal efficiency should be as high as 85 percent to 95 percent when used alone, and as high as 90 percent to 95 percent when combined with an oxidation catalyst, although emission test results will not be available until September 1999.

The product is commercially available and has been integrated into particulate filter systems that can be used on both portable and stationary engines and on turbines. The manufacturer states that the product has been used on 2,000+ vehicles with some preliminary testing in stationary applications. The manufacturer also states that some of the particulate filter systems have been in the field for 6 years and have logged 10,000+ hours of operation. The initial cost of a ceramic fiber cartridge is between $80 and $250. However, the initial cost of a particulate filter system depends on the builder and method of regeneration. The product can be used with the existing California diesel fuel formulations.

Product Name: CleanDIESEL Soot Filter
Manufacturer: Clean Air Systems
Category: Exhaust Treatment

Description:

The product reduces diesel PM, CO, and HC emissions from stationary and portable diesel-fueled engines through catalytic oxidation and filtration. The passive, self-regenerating catalyzed particulate filter system collects diesel PM and oxidizes it during hot duty cycle operations (i.e. exhaust temperatures above 700°F). The integrated catalyst reduces the particulate oxidation temperature, and it oxidizes the CO and HC emissions. For proper filter regeneration and to maintain an acceptable back pressure, the hot duty cycle must account for at least 20 percent of the engine operating time. The manufacturer states that reductions of both the SOF and the carbonaceous fraction of diesel PM can be as high as 85 percent. However, ARB has not received emission test data that support this claim.

The product is commercially available and has been installed on approximately 100 stationary, portable, and mobile diesel-fueled engines. The initial product cost ranges from $990 for a 122 cubic inch naturally aspirated engine to $20,025 for a 2,900 cubic inch turbocharged engine, and it takes between one and six hours to install. The manufacturer states that the product's useful life should be approximately 10,000 engine hours; however, the product's life may be limited on poorly maintained engines where soot can accumulate rapidly. (In this situation, the excessive soot can oxidize uncontrollably and destroy the filter.) The manufacturer recommends cleaning the product annually, and the maintenance costs include the time and materials associated with this activity. The product carries a one-year / 2,000 engine hour warranty on the

filter packaging; however, no warranty is provided on the filter media. The product can be used with the existing California diesel fuel formulations.

Product Name: Combifilter
Manufacturer: Engine Control Systems
Category: Exhaust Treatment

Description:

The product reduces diesel PM through filtration and is actively regenerated with the periodic use of electric heating. The manufacturer states that the overall diesel PM removal efficiency is between 80 percent to 90 percent. Higher reductions can be achieved when an oxidation catalyst is used in conjunction with the product. The results of one transient emission test, based on a test procedure developed specifically for a backhoe, indicated that the product when used without an oxidation catalyst reduced diesel PM emissions by 81 percent. Another set of emission tests, based upon the ISO 8-mode test, indicated that the product used in conjunction with an oxidation catalyst achieved a 95 percent reduction in diesel PM emissions, 88 percent reduction in carbon monoxide, and 92 percent reduction in hydrocarbons.

The product is commercially available in Europe and Asia and has been employed on over 3,000 diesel-fueled engines including captive fleet vehicles, stationary and mining engines. The product will be marketed in the United States later this year. The product's initial cost depends on engine size, exhaust flow rate, exhaust temperature and duty cycle, and typically varies between $5,000 and $40,000 for engines rated from 40 horsepower up to 1,400 horsepower. The filter must be cleaned every 1,000-1,500 hours, depending upon oil consumption. The product is covered by a one-year warranty and it can be used with existing California diesel fuel formulations.

Product Name: CRT Particulate Filter
Manufacturer: Johnson Matthey
Category: Exhaust Treatment

Description:

The product reduces diesel PM, CO, HC, and NOx emissions from mobile, stationary, and portable diesel-fueled engines through filtration and catalytic oxidation. The passive, self-regenerating filter system collects diesel PM and oxidizes it during hot duty cycle operations (i.e. exhaust temperatures above 530°F). A precious metal oxidation catalyst, installed upstream of a wall flow monolith filter element, converts nitrogen oxide in the exhaust stream to nitrogen dioxide, which is a strong oxidant. The product then relies on the nitrogen dioxide to oxidize the diesel PM collected on the filter element at temperatures typical for diesel-fueled engine exhaust. The catalyst also oxidizes the carbon monoxide and hydrocarbon emissions, including the SOF of diesel PM. For proper filter regeneration and operation, the hot duty cycle must account for at least 40 percent to 50 percent of the engine operating time. The manufacturer states that the overall diesel PM, CO, and HC removal efficiency can be more than 90 percent, and that the NOx removal efficiency can be as high as 10 percent. The results of one transient emission test of a 1986 2-stroke diesel-fueled transit bus engine show that, over the FTP, the product reduced diesel PM emissions by 93 percent, HC emissions by 86 percent, CO emissions by 90 percent, and NOx emissions by 2 percent.

As is the case with most processes that incorporate catalytic oxidation, the formation of sulfate particles increases at higher temperatures. Depending on the exhaust temperature and the sulfur content of the fuel, the increase in sulfate particles may offset the reduction in diesel PM emissions. Sulfur also inhibits the conversion of nitrogen oxide to nitrogen dioxide. Because of these effects, the manufacturer requires the use of ultra-low sulfur fuel. For proper regeneration, diesel with an average fuel sulfur content of 30 ppm (50 ppm max.) is required. A fuel sulfur content of less than 15 parts per million is recommend to achieve maximum diesel PM reductions.

The product is commercially available and has been installed on over 10,500 mobile diesel-fueled engines in Europe, and it is currently being demonstrated in eight heavy-duty vehicle fleets in southern California and at the New York Metropolitan Transportation Authority. The product's initial cost depends on engine size, exhaust flow rate, exhaust temperature, and duty cycle, and typically varies between $5,000 and $8,000 for engines rated up to 450 horsepower. Installation takes about four hours, and the operating costs include the incremental cost of using an ultra-low sulfur diesel fuel. The product should be cleaned every 12 months or 60,000 miles, whichever occurs first, according to the manufacturers maintenance instructions, and the maintenance costs include the time and materials associated with this cleaning activity. For urban transit bus applications, the manufacturer provides an emission

performance warranty for 150,000 miles and will replace defective parts for a period of 100,000 miles.

Product Name: DPX Particulate Filter
Manufacturer: Engelhard Corporation
Category: Exhaust Treatment

Description:

The product reduces diesel PM, CO, and HC emissions from stationary and portable diesel-fueled engines through catalytic oxidation and filtration. The passive, self-regenerating catalyzed filter system collects diesel PM and oxidizes it under normal engine exhaust temperatures. The integrated catalyst reduces the particulate oxidation temperature, and oxidizes soluble organic, CO, and HC emissions. For proper filter regeneration and operation, the hot duty cycle must account for at least 20 percent of the engine operating time. The manufacturer states that the overall diesel PM removal efficiency can be as high as 70 percent to 95 percent. The results of one emission test of a Caterpillar wheel loader, which was tested over a specially designed transient cycle, show that the product can reduce diesel PM emissions by 96 percent.

The product is commercially available and has been installed on several stationary diesel-fueled engines as well as approximately 1,000 mobile diesel-fueled engines. The manufacturer states that the product's useful life can exceed 15,000 engine hours. The product's initial cost varies between $10 and $125 per horsepower. The product should be cleaned regularly according to the maintenance instructions because lube oil ash can accumulate and increases the system's back pressure. This maintenance activity is expected to take from 2 to 4 hours per year, and the maintenance costs include the time and materials associated with this cleaning activity. When the product is installed on standby engines, the periodic engine testing should include 45 minutes of operation under load to allow for proper filter regeneration. The product carries a mechanical durability warranty of between one and two years depending on the application, and it can be used with California's existing diesel fuel formulations.

Product Name: QuadCat Four-Way Catalytic Converter
Manufacturer: Ceryx, Inc.
Category: Exhaust Treatment

Description:

The product reduces diesel PM, CO, HC, and NOx emissions from mobile, stationary, and portable diesel-fueled engines. The product consists of a lean NOx catalyst and a catalyzed diesel particulate filter (CDPF) integrated together with a heat exchanger. The lean NOx system reduces NOx, via a catalytic process, to nitrogen and water. The CDPF collects diesel PM and oxidizes the soluble organic portion of diesel PM, CO, and HC emissions. Diesel fuel is injected into the heat exchanger to ensure the catalyst is operating at the optimum temperature levels for diesel PM regeneration. The manufacturer indicates that the product is expected to achieve 90 percent reduction in CO, HC, and diesel PM emissions and 30 percent to 50 percent reduction in NOx emissions. Testing is currently being conducted by the manufacturer to verify the product's performance.

As is the case with most processes that incorporate catalytic oxidation, the formation of sulfate particles increases at higher temperatures. Depending on the exhaust temperature and the sulfur content of the fuel, the increase in sulfate particles may offset the reduction in particulate emissions. Lower fuel sulfur content is expected to enhance the performance of the product.

The product is expected to be commercially available in late 2000. Research units have been installed on a 7.3 L Navistar Powerstroke Ford F-250 and a school bus equipped with a Navistar 466 engine. The product's initial cost in mobile applications depends on engine size, exhaust flow rate, exhaust temperature, and duty cycle, and typically varies between $5,000 and $10,000 for engines rated up to 400 horsepower. Installation takes about 5 - 6 hours, and the operating costs include the cost of supplementary diesel fuel, which is typically 2 percent to 4 percent of engine fuel use at full load. The product can be used with the existing California diesel fuel formulations.

Product Name: "Trap-Muffler" System
Manufacturer: Doubletree Technologies, Inc.
Category: Exhaust Treatment

Description:

The product reduces diesel PM, HC, and NOx emissions from stationary, portable, and mobile diesel-fueled engines through filtration, exhaust gas recirculation (EGR) and oxidation. The system consists of twin particulate filters located such that the exhaust temperature remains relatively low (i.e. 100˚C to 300˚C) allowing gaseous hydrocarbons to condense on the collected diesel PM. One particulate filter is isolated and slowly regenerates while the engine's exhaust stream is directed to the second filter. Regeneration is accomplished using either an optimally located glow plug for ceramic fiber-type filters or an electric igniter coil for honeycomb-type filters. A pressure sensor-controlled diverter valve alternates between the two filters and ensures minimum exhaust backpressures.

A fuel borne catalyst is used to lower the oxidation temperature of the collected diesel PM. Alternatively, a catalyzed particulate filter can be used in place of the fuel borne catalyst when low sulfur fuel is available. In addition, a portion of the filtered and cooled exhaust stream is directed to the EGR system which further enhances hydrocarbon oxidation and minimizes the formation of NOx. The manufacturer states that the product reduces both the carbonaceous fraction and the soluble organic fraction of diesel PM, and they guarantee that the overall diesel PM removal efficiency will be at least 90 percent. However, ARB has not received emission test data that support this claim.

The product is expected to be available for commercial use in the near future. The product (absent the EGR component) has been installed on 1,100 mobile diesel-fueled engines in Seoul, Korea, although the catalyzed filters experienced durability problems related to level of sulfur in the diesel fuel. The manufacturer states that the product's useful life should be about two years, and that the individual filter elements can be easily serviced. The product's initial cost is: $1,500 for a 40 hp engine (with simplified controls); $1,700 for a 100 hp engine; $2,000 for a 275 hp engine; $2,500 for a 400 hp engine and $4,500 for a 1,400 hp engine. It takes approximately 3 - 6 hours to install the product, and the installation costs are expected to be between $300 and $600. The operating costs will include a 2 percent increase in fuel costs when a fuel borne catalyst is used. The maintenance costs are not known at this time, and the warranty has not been determined. The product can be used with California's existing diesel fuel formulations.

Product Name: Nett SF Soot Filter
Manufacturer: Nett Technologies, Inc.
Category: Exhaust Treatment

Description:

The product reduces diesel PM, CO, and HC emissions from stationary and portable diesel-fueled engines through catalytic oxidation and filtration. The passive, self-regenerating catalyzed filter system collects diesel PM and oxidizes it during hot duty cycle operations (i.e. exhaust temperatures between 700 °F and 750 °F). The integrated proprietary catalyst reduces the particulate oxidation temperature, and it oxidizes the soluble organic, CO, and HC emissions. For proper filter regeneration and operation, the hot duty cycle must account for at least 20 percent of the engine operating time. The manufacturer states that the overall diesel PM removal efficiency can be as high as 85 percent to 99 percent. One Central Business District transient driving cycle emission test of a hybrid diesel-electric bus shows that the product reduces diesel PM emissions by 92 percent, HC emissions by 41 percent, and CO emissions by 93 percent when compared to an OEM catalyst.

The product is commercially available and has been installed on approximately 200 stationary and portable diesel-fueled engines. The initial product cost, which varies with engine size, ranges from $25 to $75 per horsepower, and it takes approximately 1½ hours to install. The operating costs include a 1 percent - 1½ percent fuel penalty due to the increased backpressure, which can be as high as 20 to 40 inches of water. The manufacturer states that the product's useful life can extend from 8,000 to 12,000 engine hours, although this may be reduced in poorly maintained engines with leaking fuel injectors, dirty intake air cleaners, excessive oil consumption and/or lubricating oil in the exhaust. The manufacturer provides a 2,000 hour limited warranty on mechanical durability. The product can be used with the existing California diesel fuel formulations.

Part B: TECHNICAL EVALUATION OF TECHNOLOGIES THAT REDUCE PARTICULATE EMISSIONS FROM DIESEL-FUELED ENGINES

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DRAFT Control Technology Evaluation

Item	Response
Technology:	Catalyzed Diesel Particulate Filter
Technology Description: (How does it work?)	The technology is a passive, self-regenerating catalyzed diesel particulate filter (C-DPF). The technology reduces particulate matter, carbon monoxide and hydrocarbon emissions through catalytic oxidation and filtration. The C-DPF collects diesel particulate matter and oxidizes it during hot duty cycle operations. (This process of cleaning the C-DPF is called regeneration.) Typically, the filter media consists of ceramic wall-flow monoliths which capture the diesel particulates. These ceramic monoliths are either coated with a catalyst material or a separate catalyst is installed upstream of the C-DPF. The catalyst reduces the temperature at which the collected particulate matter oxidizes, and it oxidizes the soluble organic, carbon monoxide and hydrocarbon emissions.
Applicability: (What types of engines can the product be installed on?)	The technology is available for stationary and portable diesel engines rated at 5,000 horsepower or less and can be retrofitted to existing equipment. C-DPFs are also available for mobile diesel engines. However, the technology is not appropriate for an application where an engine and its associated duty cycle do not generate enough heat to oxidize the collected particulate matter and regenerate the filter. For example, C-DPFs may not be appropriate for engines used in severe cyclic operations.
Achieved Emission Reductions:	**Product** / **Test Cycle** / **PM Reduction** Nett SF Soot Filter / CBD Transient / 92% Engelhard DPX / Special Transient / 97% CleanDiesel Soot Filter / ISO 8178 C1 / 85%
Emission Reduction Guarantee:	The emission reduction efficiency of this technology depends on the associated engine's baseline emissions, fuel sulfur content and emission test method / cycle. As such, diesel particulate filter manufacturers do not provide emission reduction guarantees.
Costs: **Initial Retail:**	The initial cost is: $3,300 - $5,000 for a 40 hp engine; $5,000 - $7,500 for a 100 hp engine; $6,900 - $9,000 for a 275 hp engine; $10,500 for a 400 hp engine; and $32,000 - $44,000 for a 1,400 hp engine.
Installation:	$167 - $518 (Assuming 1.5 - 6 hours x $78/hr + $50 in misc parts.)
Operating:	Fuel consumption may increase by one to one and a half percent due to additional backpressure.
Maintenance:	$156 - $312 (Assuming 2 - 4 hours labor per year.)
Comments:	Diesel particulate filters should be cleaned regularly. Because of their higher backpressures (e.g. 20 - 70+ in. wc.) and the potential for masking by lube oil ash, ARB staff expect that the periodic maintenance of DPFs will be more frequent and possibly more extensive than that of diesel oxidation catalysts. ARB staff expect that the maintenance costs listed above reflect the minimum.

Item	Response
Certifications:	
Durability: (How long can the technology be expected to function under normal operating conditions and still achieve the specified emission reductions?)	Manufacturers claim that the useful life of the technology can be as high as 8,000 to 12,000 service hours if properly maintained. However, this may be reduced when a C-DPF is installed on a poorly maintained engine with leaking fuel injectors, a dirty intake air cleaner, excessive oil consumption and/or lubricating oil in the exhaust. In addition, particulate matter can build up on a C-DPF when an engine does not achieve the proper regeneration temperature for the proper duration (i.e. soot overloading). With this build up, if the C-DPF subsequently begins to regenerate, the collected particulate can oxidize uncontrollably and destroy the particulate filter.
Warranty:	Diesel particulate filters typically carry a 2,000 service hour warranty.
Affect on Engine Warranty: (When possible, identify any impact the technology may have on an engine's warranty.)	The technology imposes additional exhaust flow restrictions of between 20" to 70" of water column or more. In some applications, such as severe cyclic operations, the engine may not generate enough heat to oxidize the collected particulate matter and regenerate the filter. This can lead to soot overloading and backpressures beyond the manufacturer's recommended limit. The specific impact on an OEM engine warranty is not known.
Adverse Impacts: **Environmental:**	See "Special Operating Requirements" section below.
Safety:	No known adverse safety impacts.
Special Operating Requirements: (e.g. ultra-low sulfur fuel or minimum exhaust temperature, etc...)	As is the case with most processes that incorporate catalytic oxidation, the formation of sulfates increases at higher temperatures. Depending on the exhaust temperature and the sulfur content of the fuel, the increase in sulfate particles may offset a portion of the C-DPF's particulate reductions. In addition, sulfur dioxide can counteract the effect of the catalyst material and increase the C-DPF's regeneration temperature. Diesel fuel with a very low sulfur content will maximize the emission reduction capability of this technology.
	C-DPFs must be selected for the specific engine and its associated duty cycle. All engines must be able to maintain the minimum regeneration temperature (which varies by product) for at least 20% - 50% of the engine's duty cycle.
Current Status: (Is the technology commercially available, or is it still under development? How many engines has the technology been installed on, and how long has the technology been in use?)	The technology is commercially available. According to the VERT study [1999], C-DPFs have been installed on several thousand mobile diesel-fueled engines. The technology has also been installed on a few stationary diesel-fueled engines.

Item	Response
Other: (e.g. fuel penalty, reduced product life, weight, affect on engine performance, etc...)	The size and weight of one manufacturer's C-DPFs are as follows: **HP** — **Diameter** — **Length** — **Weight** 40 — 8.1" — 18.5" — 17 lb 100 — 9.6" — 25.5" — 34 lb 275 — 11.9" — 30.6" — 47 lb 400 — 15.7" — 34.2" — 87 lb 1,400 — 2@ 20.7" — 38.2" — 151 lb The determination of whether or not a used C-DPF would be considered a "hazardous waste" depends on the material(s) used in the catalytic coating. C-DPFs can be manufactured with catalytic coatings such that the product would not be considered a hazardous waste at the end of its useful life. Further, the Department of Toxic Substances Control currently regulates used automotive catalytic converters as scrap metal as long as the catalyst is left in the converter shell during collection and transport and the converters are going for recycling. The ash residue associated with cleaning and maintaining a C-DPF would need to be tested before a hazardous waste determination could be made.
Impacts of Lower Sulfur Diesel Fuel	Use of diesel fuel with a very low sulfur content will improve the technology's particulate reduction efficiency. A recent study sponsored by the U.S. Department of Energy (DOE) found that fuel sulfur levels have a significant impact on the ability of C-DPFs to reduce particulate emissions. The study also concluded that fuel sulfur levels of less than 150 ppm are necessary in order to achieve reductions in particulate emission from some C-DPFs.
Comments: (Address other issues relevant to the use of this technology, including other advantages / disadvantages of using the technology.)	In addition to reducing particulate emissions, the technology also reduces carbon monoxide and hydrocarbon emissions.

List of Applications

Technology Name: Catalyzed Diesel Particulate Filter

Facility / Operator	Engine Information	Permit / Registration	Number of Applications	Time in Service	PM Emission Limit	PM Emission Test Results
Sierra Nevada Brewing Company, Inc. Chico, CA	Make: Caterpillar Model: 3412 Application: Generator Fuel Type: Shell Amber 363 DPF: Engelhard DPX	Authority to Construct No. SNB-99-09-AC Issued by Butte County AQMD	Two C-DPFs installed on each of two emergency backup generators.	Recent Installation	0.0584 lb/hr	Emission testing completed in March 2000. Results pending.
New York Metropolitan Transportation Authority[1]	Make: Detroit Diesel Model: Series 50 Application: Transit Bus Fuel Type: Reduced Sulfur Diesel (30 ppm S) DPF: Johnson Matthey CRT	n/a	22	Since February 2000	n/a	Pending
San Diego School District[2]	Make: International Model: 530E Application: School Bus Fuel Type: ARCO EC-D DPF: Engelhard DPX & Johnson Matthey CRT	n/a	5 w/ DPX 5 w/ CRT	Since December 1999	n/a	See List of Emission Test Results

[1] New York MTA Clean Diesel Demonstration Program. As part of this program, the New York MTA intends to evaluate the technology on twentyfive DDC Series 50 and twentyfive DDC 6V92 transit bus engines over a one year period.

[2] Fleet managed by Navistar as part of the ARCO EC-D Demonstration Program.

Facility / Operator	Engine Information	Permit / Registration	Number of Applications	Time in Service	PM Emission Limit	PM Emission Test Results
ARCO Distribution[3]	Make: Cummins Model: M11 Application: Tanker Truck Fuel Type: ARCO EC-D DPF: Engelhard DPX & Johnson Matthey CRT	n/a	5 w/ DPX 5 w/ CRT	Unknown	n/a	See List of Emission Test Results
Ralphs Grocery[4]	Make: Detroit Diesel Model: Series 60 Application: Grocery Truck Fuel Type: ARCO EC-D DPF: Engelhard DPX & Johnson Matthey CRT	n/a	5 w/ DPX 5 w/ CRT	Unknown	n/a	See SAE paper 2000-01-1854 for detailed emission test results.
Swedish Public Transportation Association	Make: Unknown Model: Unknown Application: Transit Bus Fuel Type: Low Sulfur Diesel DPF: Johnson Matthey CRT	n/a	1994: 10 Buses 1996: 1,000 Buses 1999: 2,000 Buses 1999: 1,000 Trucks		Unknown	Unknown

[3] Fleet managed by ARCO as part of the ARCO EC D-Demonstration Program.

[4] Fleet managed by the National Renewable Energy laboratory (NREL) as part of the ARCO EC-D Demonstration Program.

List of Emission Test Results

Technology Name: Catalyzed Diesel Particulate Filter

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Control Efficiency
Central Business District (CBD)	Environment Canada, Emission Research and Measurement Division, Report #97-26771-3 (Unpublished)	Nett SF Soot Filter Mfg. by Nett Technologies	Make: Navistar Model: T444 Diesel-Electric Year: Not known BHP: Not known Application: Hybrid Diesel-Electric Transit Bus Configuration: Not known Engine Hours: Not known Fuel Type: Certification Diesel D2 Fuel Use: Not known Exhaust Temp: Not known		w/ oxidation catalyst	600 rpm Config.	
				PM	0.318 g/mile	0.036 g/mile	89%
				NOx	10.66 g/mile	11.16 g/mile	-5%
				CO	1.78 g/mile	0.12 g/mile	93%
				HC	0.22 g/mile	0.04 g/mile	82%
					w/ oxidation catalyst	750 rpm Config.	
				PM	0.318 g/mile	0.027 g/mile	92%
				NOx	10.66 g/mile	10.62 g/mile	0%
				CO	1.78 g/mile	0.13 g/mile	93%
				HC	0.22 g/mile	0.13 g/mile	41%
Special transient cycle designed for a specific wheel loader application.[5]	Emissions Research and Measurement Division, Environment Canada	DPX Particulate Filter Mfg. by Engelhard Corporation	Make: Caterpillar Model: 988 Year: Unknown BHP: 320 Application: Wheel loader Configuration: Unknown Engine Hours: Unknown Fuel Type: 530 ppm S Diesel Fuel Use: 15.8 kg/hr Exhaust Temp: Unknown	PM	17.38 g/hr	0.59 g/hr	97%
				NOx	290.72 g/hr	224.96 g/hr	23%
				CO	112.65 g/hr	35.67 g/hr	68%
				HC	9.32 g/hr	2.96 g/hr	68%

[5] Study reported in SAE Technical Paper #1999-01-0110 entitled "The Impact of Retrofit Exhaust Control Technologies on Emissions from heavy-Duty Diesel Construction Equipment."

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Control Efficiency
ISO 8178 C1	AB Svensk Motor Test Center	CleanDiesel Soot Filter Mfg. by Clean Air Systems	Make: Volvo Model: TD61-G Year: Unknown BHP: 78 hp Application: Mobile Source Configuration: Unknown Engine Hours: Unknown Fuel Type: 50 ppm S MK-1 Diesel Fuel Use (lb/hp-hr): 0.376 / 0.380 Exhaust Temp: Unknown	PM NOx CO HC	0.14 g/bhp-hr 9.55 g/bhp-hr 2.33 g/bhp-hr 0.22 g/bhp-hr	0.02 g/bhp-hr 9.17 g/bhp-hr 0.02 g/bhp-hr 0.01 g/bhp-hr	85% 4% 99% 97%
European Stationary Cycle (OICA)[6]	Engineering Test Services, Charleston, SC	Catalyzed Diesel Particulate Filter	Make: Caterpillar Model: 3126 Year: 1998 or 1999 BHP: 275 horsepower Application: N/A Configuration: Turbocharged & Aftercooled Engine Hours: Not Reported Fuel Type: Diesel w/ varying fuel sulfur levels Fuel Use (lb/hp-hr): 0.35 - 0.36 Exhaust Temp: Not Reported	<u>3 ppm Sulfur</u> PM NOx CO HC	<u>3 ppm Sulfur</u> 0.0613 g/hphr 4.94 g/hphr 0.98 g/hphr 0.0542 g/hphr	<u>3 ppm Sulfur</u> 0.0031 g/hphr 4.92 g/hphr 0.06 g/hphr 0.0228 g/hphr	 95% 0% 94% 58%
				<u>30 ppm Sulfur</u> PM NOx CO HC	<u>30 ppm Sulfur</u> 0.063 g/hphr 4.98 g/hphr 0.96 g/hphr 0.056 g/hphr	<u>30 ppm Sulfur</u> 0.0166 g/hphr 4.8 g/hphr 0.02 g/hphr 0.0182 g/hphr	 74% 4% 98% 68%
				<u>150 ppm S</u> PM NOx CO HC	<u>150 ppm S</u> 0.0708 g/hphr 4.85 g/hphr 1.04 g/hphr 0.0586 g/hphr	<u>150 ppm Sulfur</u> 0.0707 g/hphr 4.87 g/hphr 0.02 g/hphr 0.0105 g/hphr	 0% 0% 98% 82%
				<u>350 ppm S</u> PM NOx CO HC	<u>350 ppm S</u> 0.0793 g/hphr 4.91 g/hphr 0.94 g/hphr 0.0565 g/hphr	<u>350 ppm Sulfur</u> 0.176 g/hphr 4.69 g/hphr 0.03 g/hphr 0.0194 g/hphr	 -122% 4% 97% 66%

[6] Emission test results reported in "Diesel Emission Control - Sulfur Effects (DECSE) Program, Phase I Interim Data Report No. 4: Diesel Particulate Filters - Final Report," January 2000.

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Control Efficiency
European Stationary Cycle (OICA)[7]	Engineering Test Services, Charleston, SC	Continuously Regenerating Diesel Particulate Filter	Make: Caterpillar Model: 3126 Year: 1998 or 1999 BHP: 275 horsepower Application: N/A Configuration: Turbocharged & Aftercooled Engine Hours: Not Reported Fuel Type: Diesel w/ varying fuel sulfur levels Fuel Use (lb/hp-hr): 0.35 - 0.36 Exhaust Temp: Not Reported		3 ppm Sulfur	3 ppm Sulfur	
				PM	0.0613 g/hphr	0.0032 g/hphr	95%
				NOx	4.94 g/hphr	4.96 g/hphr	0%
				CO	0.98 g/hphr	0.1 g/hphr	90%
				HC	0.0542 g/hphr	0.0136 g/hphr	75%
					30 ppm Sulfur	30 ppm Sulfur	
				PM	0.063 g/hphr	0.0176 g/hphr	72%
				NOx	4.98 g/hphr	4.84 g/hphr	3%
				CO	0.96 g/hphr	0.06 g/hphr	94%
				HC	0.056 g/hphr	0.0052 g/hphr	91%
					150 ppm S	150 ppm Sulfur	
				PM	0.0708 g/hphr	0.0729 g/hphr	-3%
				NOx	4.85 g/hphr	4.88 g/hphr	-1%
				CO	1.04 g/hphr	0.06 g/hphr	94%
				HC	0.0586 g/hphr	0.0189 g/hphr	68%
					350 ppm S	350 ppm Sulfur	
				PM	0.0793 g/hphr	0.2025 g/hphr	-155%
				NOx	4.91 g/hphr	4.81 g/hphr	2%
				CO	0.94 g/hphr	0.05 g/hphr	95%
				HC	0.0565 g/hphr	0.0064 g/hphr	89%

[7] Emission test results reported in "Diesel Emission Control - Sulfur Effects (DECSE) Program, Phase I Interim Data Report No. 4: Diesel Particulate Filters - Final Report," January 2000.

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Control Efficiency
Federal Test Procedure[8]	Southwest Research Institute, Inc.	One Individual Diesel Particulate Filters	Make: Detroit Diesel Corporation Model: DDC 6067TK60 (DDC Series 60) Year:1998 BHP: 400 hp Application: Heavy Duty Vehicle Configuration: Turbocharged & Aftercooled Engine Hours: Not Reported Fuel Type: 368 ppm S Diesel Fuel Use (lb/bhp-hr): 0.393 - 0.401 Exhaust Temp: Approx 100-800˚F			DPF "A"	
				PM NOx CO HC	0.073 g/bhp-hr 3.991 g/bhp-hr 1.111 g/bhp-hr 0.115 g/bhp-hr	0.022 g/bhp-hr 3.960 g/bhp-hr 0.403 g/bhp-hr 0.006 g/bhp-hr	70% 1% 64% 95%
Federal Test Procedure [8]	Southwest Research Institute, Inc.	Two Individual Diesel Particulate Filters	Make: Detroit Diesel Corporation Model: DDC 6067TK60 (DDC Series 60) Year:1998 BHP: 400 hp Application: Heavy Duty Vehicle Configuration: Turbocharged & Aftercooled Engine Hours: Not Reported Fuel Type: 54 ppm S Diesel Fuel Use (lb/bhp-hr): 0.396 - 0.402 Exhaust Temp: Approx 100-800˚F			DPF "B"	
				PM NOx CO HC	0.063 g/bhp-hr 3.836 g/bhp-hr 1.200 g/bhp-hr 0.109 g/bhp-hr	0.008 g/bhp-hr 3.901 g/bhp-hr 0.077 g/bhp-hr 0.005 g/bhp-hr	87% -2% 94% 95%
						DPF "A"	
				PM NOx CO HC	0.063 g/bhp-hr 3.836 g/bhp-hr 1.200 g/bhp-hr 0.109 g/bhp-hr	0.006 g/bhp-hr 4.062 g/bhp-hr 0.267 g/bhp-hr 0.019 g/bhp-hr	90% -6% 78% 83%

[8] The FTP emission test information was presented in the May 1999 report "Demonstration of Advanced Emission Control Technologies Enabling Diesel-Powered Heavy-Duty Engines to Achieve Very Low Emission Levels" prepared for the Manufacturers of Emission Controls Association by Southwest Research Institute, Inc.

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Control Efficiency
Federal Test Procedure[9]	Southwest Research Institute, Inc.	Continuously Regenerating Trap (CRT) by Johnson Matthey	Make: Detroit Diesel Corporation Model: 6V92TA MUI Year: 1986 BHP: 253 hp Application: Transit Bus Configuration: Turbocharged & Aftercooled Engine Miles: Over 300,000 miles Fuel Type: 2-D Certification Diesel Fuel Use (lb/hr): 64.8 - 66.6 Exhaust Temp: Not Reported Note: Pre-Rebuild w/ CRT & Uninsulated	 PM NOx CO HC	500 ppm S 0.44 g/bhp-hr 10.5 g/bhp-hr 1.0 g/bhp-hr 0.7 g/bhp-hr	100 ppm S 0.03 g/bhp-hr 10.3 g/bhp-hr 0.1 g/bhp-hr 0.1 g/bhp-hr	 93% 2% 90% 86%
City-Suburban heavy Vehicle Route (CSHVR)[10]	West Virginia University	Engelhard DPX Particulate Filter	Make: International Model: 530E Year: 1988 BHP: 275 hp Application: School Bus Configuration: Not Reported Engine Miles: Not Reported Fuel Type: ARCO EC-D Fuel Use (mpg): 4.68/5.09 4.46/4.49 Exhaust Temp: Not Reported	 PM NOx CO HC PM NOx CO HC	Bus 3 0.180 g/mile 18.14 g/mile 2.06 g/mile 0.466 g/mile Bus 4 0.192 g/mile 18.11 g/mile 2.45 g/mile 0.487 g/mile	Bus 3 0.000 g/mile 16.05 g/mile 0.11 g/mile 0.000 g/mile Bus 4 0.000 g/mile 16.45 g/mile 0.18 g/mile 0.000 g/mile	Bus 3 100% 11% 95% 100% Bus 4 100% 9% 93% 100%

[9] The emission test information was submitted to support Johnson Matthey's application for certification of a Low Sulfur 0.1 g/bhp-hr PM Emissions Reduction Rebuild Kit for all transit engines.

[10] Emission test results reported in SAE paper 2000-01-1854 entitled "EC-Diesel Technology Validation Program Interim Report." (Unpublished)

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Control Efficiency
City-Suburban heavy Vehicle Route (CSHVR)[11]	West Virginia University	Johnson Matthey CRT Particulate Filter	Make: Cummins Model: M11 Year: 1995-96 BHP: 330 hp Application: Tanker Truck Configuration: Not Reported Engine Miles: Not Reported Fuel Type: ARCO EC-D Fuel Use (mpg): 5.92/5.53 & 4.79/4.95 Exhaust Temp: Not Reported		Truck 3	Truck 3	Truck 3
				PM	0.510 g/mile	0.015 g/mile	97%
				NOx	14.05 g/mile	12.49 g/mile	11%
				CO	3.25 g/mile	0.49 g/mile	85%
				HC	1.026 g/mile	0.068 g/mile	93%
					Truck 4	Truck 4	Truck 4
				PM	0.613 g/mile	0.037 g/mile	94%
				NOx	15.26 g/mile	15.37 g/mile	-1%
				CO	2.53 g/mile	0.15 g/mile	94%
				HC	1.456 g/mile	0.153 g/mile	89%

[11] Emission test results reported in SAE paper 2000-01-1854 entitled "EC-Diesel Technology Validation Program Interim Report." (Unpublished)

DRAFT Control Technology Evaluation

Item	Response		
Product Name:	Platinum Plus® DFX Fuel Borne Catalyst + Diesel Particulate Filter		
Product Vendor:	Clean Diesel Technologies, Inc.		
Vendor Address:	300 Atlantic Street, Suite 702 Stamford, CT 06901-3522		
Product Description: (What is the product, and how does it work?)	The technology involves combining the use of a concentrated liquid fuel-borne catalyst (FBC) with an uncatalyzed or lightly catalyzed Diesel Particulate Filter (DPF). The technology reduces particulate matter emissions through catalytic oxidation and filtration. The FBC contains low doses (i.e. 4 ppm - 8 ppm) of platinum and cerium that work together to improve particulate oxidation within the combustion chamber and to lower the temperature at which regeneration occurs within a DPF. While similar to a catalyzed DPF, an FBC enhances DPF regeneration by encouraging better contact between the particulate matter and the catalyst material. The FBC+DPF combination reduces both the carbonaceous and soluble organic fractions of diesel PM.		
Applicability: (What types of engines can the product be installed on?)	The technology can be applied to all stationary and portable diesel-fueled engines rated at 5,000 horsepower or less, and can be retrofitted to existing equipment. However, the technology may not be appropriate for applications where an engine and its associated duty cycle do not generate enough heat to oxidize the collected particulate matter and regenerate the filter. For example, the FBC+DPF combination may not be appropriate for engines with exhaust temperatures routinely below 540˚F. The FBC manufacturer recommends that an FBC+DPF equipped engine operate such that the exhaust gas temperatures reach 660˚F for at least 20 minutes during each 8 hour period of operation.		
Manufacturer's Emission Reduction Claim: (What level of emission reduction can be achieved?)	The manufacturer claims that the technology reduces particulate emissions by 70% - 95%.		
Emission Reduction Guarantee:	The manufacturer's emission reduction guarantee depends on the engine's baseline emission level.		
Certifications: (Identify certifications the product has received, and explain any limits on those certifications.)	Platinum Plus is registered by the U.S. Environmental Protection Agency as a diesel fuel additive.		
Emission Test Results: (Summarize emission test results and describe in detail on the attached table.)	**Engine Make/Model**	**Test Cycle**	**PM Reduction**
	DDC Series 60	FTP Transient	57% - 96%
	Cummins 6BTA	FTP Transient	95%
	Cummins N-14	FTP Transient	79%

Item	Response
Costs: **Initial Retail:**	The cost of uncatalyzed or lightly catalyzed particulate filters varies by engine size as follows: $1,300 for a 40 hp engine; $2,000 for a 100 hp engine; $3,500 for a 275 hp engine; $7,000 for a 400 hp engine; and $30,000 for a 1,400 hp engine. The cost of on -board dosing systems is approximately $1,500 - $3,000 for a field retrofit, and $500 - $1,000 if factory installed.
Installation:	$167 - $518 (Assuming 1.5 - 6 hours x $78/hr + $50 in misc parts.)
Operating:	The cost of the FBC is $0.05 - $0.10 per gallon of diesel for bulk treatment or on-board dosing, and $0.10 - $0.15 per gallon of diesel for individually packaged products (quart or gallon containers).
Maintenance:	$156 - $312 (Assuming 2 - 4 hours labor per year.)
Comments:	Diesel particulate filters should be cleaned regularly. Because of higher backpressures and the potential for masking by lube oil ash, ARB staff expects that the periodic maintenance of DPFs will be more frequent and possibly more extensive than that of diesel oxidation catalysts. ARB staff expects that the maintenance costs listed above reflect the minimum.
Durability / Product Life: (How long can the technology be expected to function under normal operating conditions and still achieve the specified emission reductions?)	The manufacturer states that the shelf life of Platinum Plus, when packaged individually, is 24 months, and that its shelf life is 12 - 18 months when mixed with diesel fuel.
	Manufacturers claim that the useful life of a DPF can be as high as 8,000 to 12,000 service hours if properly maintained. However, this may be reduced when a DPF is installed on a poorly maintained engine with leaking fuel injectors, a dirty intake air cleaner, excessive oil consumption and/or lubricating oil in the exhaust. In addition, particulate matter can build up on a DPF when an engine does not achieve the proper regeneration temperature for the proper duration (i.e. soot overloading). With this build up, if the DPF subsequently begins to regenerate, the collected particulate matter can oxidize uncontrollably and destroy the filter. Because the product lowers particulate oxidation temperatures, it can reduce the risk of plugging and uncontrolled regeneration.
Product Warranty:	DPFs typically carry a 2,000 service hour warranty.
Affect on Engine Warranty: (When possible, identify any impact the technology may have on an engine warranty.)	The engine manufacturer should be contacted to determine the specific impact of an FBC+DPF combination on an OEM engine warranty.
Adverse Impacts: **Environmental:**	One FTP emission test suggests that the application of the FBC+DPF combination on an engine equipped with exhaust gas recirculation (EGR) may increase hydrocarbon emissions. See Comments section.
Safety:	There are no known adverse safety impacts.

Item	Response
Special Operating Requirements: (e.g. ultra-low sulfur fuel or minimum exhaust temperature, etc...)	The FBC manufacturer recommends that an FBC+DPF equipped engine operate such that the exhaust gas temperatures reach 660˚F for at least 20 minutes during each 8 hour period of engine operation. In addition, the exhaust temperature should be maintained below 930˚F to avoid and/or minimize sulfation.
Current Status: (Is the technology commercially available, or is it still under development? How many engines has the technology been installed on, and how long has the technology been in use?)	The technology is commercially available and has been applied to over 100 city buses in Taiwan, six buses in Hong Kong, and twelve pieces of construction and mining equipment in Germany and Switzerland.
Other: (e.g. fuel penalty, reduced product life, weight, affect on engine performance, etc...)	The available emission test data shows that fuel economy varies from an increase of 2% to a decrease of 3%.
Impacts of Lower Sulfur Diesel Fuel	Although the technology can be applied to existing California diesel fuel formulations with sulfur contents up to 500 ppm, the use of low sulfur diesel fuel should improve the emission reduction efficiency of this technology.
Comments: (Address other issues relevant to the use of this technology, including other advantages / disadvantages of using the technology.)	The FBC+DPF technology appears to have a variable effect on hydrocarbon emissions. When tested on a DDC Series 60 engine equipped with EGR, hydrocarbon emissions increased by approximately 150% although the emissions did not exceed the applicable NOx+HC standard. However, other tests on the same engine without EGR show hydrocarbon reductions of 57% - 82%. When tested on a Cummins N-14 engine, hydrocarbon emissions were reduced by 80%, and when tested on a Cummins 6BTA engine, they were reduced by 64%. The manufacturer suggests that, when used with a lightly catalyzed DPF, the FBC+DPF combination can dramatically reduce both hydrocarbon and carbon monoxide emissions. In addition to selecting a precatalyzed DPF, a filter can be lightly catalyzed by conditioning it for 20 hours on FBC treated fuel.

List of Stationary &/or Portable Applications

Technology Name: Platinum Plus Fuel Borne Catalyst + Diesel Particulate Filter

Facility / Operator	Engine Information	Permit / Registration	Number of Applications	Time in Service	PM Emission Limit	PM Emission Test Results
There are no known stationary or portable applications of this technology.	Make: Model: Application: Fuel Type:					

List of Emission Test Results

Technology Name: Platinum Plus Fuel Borne Catalyst + Diesel Particulate Filter

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Control Efficiency
FTP Transient	Southwest Research Institute	Clean Diesel Technology Platinum Plus DFX + Diesel Particulate Filter	Make: Detroit Diesel Corporation Model: Series 60 Year: 1998 BHP: 400 Application: Heavy Duty Vehicle Configuration: Turbocharged, Aftercooled, EGR Engine Hours: Not Reported Fuel Type: No. 2 Diesel (368 ppm S) Fuel Use (lb/hp-hr): 0.408 / 0.400 Exhaust Temp: Not Reported	PM NOx CO HC	0.204 g/bhp-hr 2.492 g/bhp-hr 2.528 g/bhp-hr 0.063 g/bhp-hr	0.009 g/bhp-hr 2.312 g/bhp-hr 1.863 g/bhp-hr 0.156 g/bhp-hr	96% 7% 26% -148%
FTP Transient	Southwest Research Institute	Clean Diesel Technology Platinum Plus DFX + Diesel Particulate Filter	Make: Detroit Diesel Model: Series 60 Year: 1998 BHP: 400 Application: Heavy Duty Vehicle Configuration: Turbocharged Engine Hours: Not Reported Fuel Type: Diesel (350 ppm S) Fuel Use (lb/hp-hr): 0.403 / 0.409 Exhaust Temp: Not Reported	PM NOx CO HC	0.074 g/bhp-hr 4.051 g/bhp-hr 1.128 g/bhp-hr 0.146 g/bhp-hr	0.014 g/bhp-hr 4.048 g/bhp-hr 0.658 g/bhp-hr 0.049 g/bhp-hr	81% 0% 42% 66%

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Control Efficiency
FTP Transient	Southwest Research Institute	Clean Diesel Technology Platinum Plus DFX + Diesel Particulate Filter	Make: Detroit Diesel Model: Series 60 Year: 1998 BHP: 400 Application: Heavy Duty Vehicle Configuration: Turbocharged Engine Hours: Not Reported Fuel Type: Diesel (350 ppm S) Fuel Use (lb/hp-hr): 0.403 / 0.416 Exhaust Temp: Not Reported	PM NOx CO HC	0.074 g/bhp-hr 4.051 g/bhp-hr 1.128 g/bhp-hr 0.146 g/bhp-hr	0.017 g/bhp-hr 3.969 g/bhp-hr 0.665 g/bhp-hr 0.071 g/bhp-hr	77% 2% 41% 51%
FTP Transient	Southwest Research Institute	Clean Diesel Technology Platinum Plus DFX + *Catalyzed* Diesel Particulate Filter	Make: Detroit Diesel Model: Series 60 Year: 1998 BHP: 400 Application: Heavy Duty Vehicle Configuration: Turbocharged Engine Hours: Not Reported Fuel Type: Diesel (350 ppm S) Fuel Use (lb/hp-hr): 0.403 / 0.400 Exhaust Temp: Not Reported	PM NOx CO HC	0.074 g/bhp-hr 4.051 g/bhp-hr 1.128 g/bhp-hr 0.146 g/bhp-hr	0.032 g/bhp-hr 3.953 g/bhp-hr 0.411 g/bhp-hr 0.032 g/bhp-hr	57% 2% 64% 78%
FTP Transient	Southwest Research Institute	Clean Diesel Technology Platinum Plus DFX + *Catalyzed* Diesel Particulate Filter	Make: Detroit Diesel Model: Series 60 Year: 1998 BHP: 400 Application: Heavy Duty Vehicle Configuration: Turbocharged Engine Hours: Not Reported Fuel Type: Diesel Fuel Use (lb/hp-hr): 0.403 / 0.408 Exhaust Temp: Not Reported	 PM NOx CO HC	No. 2 Diesel (350 ppm S) 0.074 g/bhp-hr 4.051 g/bhp-hr 1.128 g/bhp-hr 0.146 g/bhp-hr	CARB Diesel (50 ppmS) 0.013 g/bhp-hr 3.786 g/bhp-hr 0.342 g/bhp-hr 0.018 g/bhp-hr	 82% 7% 70% 88%

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Control Efficiency
FTP Transient	Cummins Engine Company	Clean Diesel Technology Platinum Plus 3100C & Rhone-Poulenc Eolys DPX9 + Diesel Particulate Filter	Make: Cummins Model: Encore 6BTA Year: 1996 BHP: 225 Application: Medium Duty Vehicle Configuration: EGR Engine Hours: 400 hrs Fuel Type: Diesel (350 ppm S) Fuel Use (lb/hp-hr): Not Reported Exhaust Temp: Not Reported	PM NOx CO HC	0.231 g/bhp-hr 2.64 g/bhp-hr 1.44 g/bhp-hr 0.22 g/bhp-hr	0.011 g/bhp-hr 2.14 g/bhp-hr 1.39 g/bhp-hr 0.08 g/bhp-hr	95% 19% 3% 64%
FTP Transient (Hot Start Only)	Southwest Research Institute	Platinum Plus DFX + Diesel Particulate Filter	Make: Cummins Model: N-14 Year: 1998 BHP: 370 Application: Heavy Duty Vehicle Configuration: Not Reported Engine Hours: 1000 Fuel Type: Diesel Fuel Use (lb/hp-hr): 0.393 / 0.391 Exhaust Temp: Not Reported	PM NOx CO HC	0.100 g/bhp-hr 3.869 g/bhp-hr 0.505 g/bhp-hr 0.174 g/bhp-hr	0.021 g/bhp-hr 3.628 g/bhp-hr 0.487 g/bhp-hr 0.035 g/bhp-hr	79% 6% 4% 80%

DRAFT Control Technology Evaluation

Item	Response
Technology:	Diesel Oxidation Catalyst
Technology Description: (How does it work?)	The technology reduces carbon monoxide (CO), hydrocarbons (HC), and the soluble organic fraction (SOF) of diesel particulate matter through catalytic oxidation. In the presence of a catalyst material and oxygen, CO, HC, & SOF undergo a chemical reaction and are converted into carbon dioxide and water. Some manufacturers integrate hydrocarbon traps (zeolites) and sulfate suppressants into their oxidation catalysts. Hydrocarbon traps enhance HC reduction efficiency at lower exhaust temperatures and sulfate suppressants minimize the generation of sulfates at higher exhaust temperatures.
Applicability: (What types of engines can the product be installed on?)	The technology is available for stationary and portable diesel-fueled engines between four horsepower and 5,000 horsepower and can be retrofitted to existing equipment.
Achieved Emission Reductions: (Summarize emission test results and describe in detail on the attached table.)	**Product** / **Test Cycle** / **PM Reduction** Nett D-Series / 5-Mode Steady State / 21% CEP Dieselytic SX / 8-Mode Steady State / 16% Engelhard PTX / Special Transient / 24% Engelhard CMX / FTP Transient / 30%
Emission Reduction Guarantee:	The emission reduction efficiency of this technology depends on the associated engine's baseline emissions, fuel sulfur content and emission test method / cycle. As such, diesel oxidation catalyst (DOC) manufacturers do not provide emission reduction guarantees.
Certifications: (Identify certifications the technology has received, and explain any limits on the certifications.)	Several models have been certified under EPA's Urban Bus Retrofit/Rebuild program.
Product Costs: **Initial Retail:**	The initial cost range is: $400 - $600 for a 40 hp engine; $680 - $1,356 for a 100 hp engine; $2,100 - $2,600 for a 275 hp engine; $2,800 - $3,700 for a 400 hp engine; and $10,000 - $20,000 for a 1,400 hp engine.
Installation:	Approx. $167 (Assuming 1.5 hours x $78/hr + $50 in misc parts.)
Operating:	None
Maintenance:	$64/year - $712/year (Assumes $50 - $100 for thermal cleaning and 1 hour labor (at $78/hour): once every other year to 4 times per year, depending on manufacturer recommendations and application)
Comments:	The technology requires periodic maintenance which may include thermal cleaning. The frequency of the maintenance depends on the manufacturer and application and varies from biennially to four times per year. The maintenance costs above reflect this schedule.

Item	Response
Durability: (How long can the technology be expected to function under normal operating conditions and still achieve the specified emission reductions?)	Manufacturers claim that the useful life of the technology depends on the application, and that it varies between 4,000 and 10,000 service hours. However, the useful life generally appears to be consistent with the rebuild cycle of the associated engine: one manufacturer recommends replacing the catalyst at the time an engine is rebuilt. Another manufacturer claims that their product's useful life can extend to 25,000 service hours, but this depends on the condition of the engine, type of fuel and maintenance practices.
Product Warranty: (Identify the type of warranty and its duration.)	Diesel oxidation catalysts typically carry a 2,000 service hour warranty.
Affect on Engine Warranty: (When possible, identify any impact the technology may have on an engine's warranty.)	The technology imposes additional exhaust gas flow restrictions of between 4 - 11 inches of water column; however, the additional restriction is expected to be within the manufacturer's specifications. As such, the technology is not expected to have an impact on an OEM engine warranty.
Adverse Impacts: Environmental:	As is the case with most processes that incorporate catalytic oxidation, the formation of sulfates increases at higher temperatures. Depending on the exhaust temperature and the sulfur content of the fuel, the increase in sulfate particles may offset the reductions in SOF emissions. This effect can be minimized by using diesel fuel with a very low sulfur content.
Safety:	There are no known adverse safety impacts.
Special Operating Requirements: (e.g. ultra-low sulfur fuel or minimum exhaust temperature, etc...)	One manufacturer recommends cleaning their product every 6 months or 2,000 service hours (whichever occurs first) when it is installed on newer engines, and every 3 months or 1,000 service hours (whichever occurs first) when it is installed on older engines. The catalyst can be cleaned by the engine operator by either: 1) applying a compressed air stream to the face of the catalyst; 2) heat treating the catalyst core; or 3) soaking the catalyst in an appropriate solvent.
Current Status: (Is the technology commercially available, or is it still under development? How many engines has the technology been installed on, and how long has the technology been in use?)	The technology is commercially available and has been installed on tens of thousands of mobile diesel-fueled engines. The technology has also been applied to several stationary diesel-fueled engines.

<table>
<tr><th>Item</th><th>Response</th></tr>
<tr><td>Other:
(e.g. fuel penalty, reduced product life, weight, affect on engine performance, etc...)</td><td>The typical size and weight of DOCs vary as follows:
<table>
<tr><th>HP</th><th></th><th>Diameter</th><th>Length</th><th>Weight</th></tr>
<tr><td>40</td><td></td><td>3.6" - 4.6"</td><td>8.4" - 9.0"</td><td>1.8 lb - 6 lb</td></tr>
<tr><td>100</td><td></td><td>5.6" - 6.6"</td><td>10.2" - 10.5"</td><td>4 lb - 15 lb</td></tr>
<tr><td>275</td><td></td><td>8.8" - 8.9"</td><td>18"</td><td>14.8 lb - 32 lb</td></tr>
<tr><td>400</td><td></td><td>8.8" - 11.9"</td><td>18" - 20"</td><td>20.3 lb - 37 lb</td></tr>
<tr><td>1,400</td><td>2@</td><td>8.8" - 14.9"</td><td>20" - 20.8"</td><td>29.8 lb - 58.5 lb</td></tr>
</table>
The determination of whether or not a used DOC would be considered a “hazardous waste” depends on the material(s) used in the catalytic coating. DOCs can be manufactured with catalytic coatings such that the product would not be considered a hazardous waste at the end of its useful life. Further, the Department of Toxic Substances Control currently regulates used automotive catalytic converters as scrap metal as long as the catalyst is left in the converter shell during collection and transport and the converters are going for recycling.

The ash residue associated with cleaning and maintaining a DOC would need to be tested before a hazardous waste determination could be made.</td></tr>
<tr><td>Impacts of Lower Sulfur Diesel Fuel</td><td>Use of diesel fuel with a very low sulfur content will improve the technology’s particulate reduction efficiency. One manufacturer recommends using diesel fuel with a maximum sulfur content of 500 ppm and an aromatics content of less than 18%. A second manufacturer suggests that using diesel fuel with a sulfur content of less than 500 ppm will enhance the durability and performance of their product.</td></tr>
<tr><td>Comments:
(Address other issues relevant to the use of this technology, including other advantages / disadvantages of using the technology.)</td><td>In addition to reducing the soluble organic fraction of diesel particulate matter, the product also reduces carbon monoxide and hydrocarbon emissions.</td></tr>
</table>

List of Applications

Technology Name: Diesel Oxidation Catalyst

Facility / Operator	Engine Information	Permit / Registration	Number of Applications	Time in Service	PM Emission Limit	PM Emission Test Results
New York City Metropolitan Transportation Authority	Make: Detroit Diesel Model: Series 50 & 6V92 Application: Transit Bus Fuel Type: No. 1 Diesel / Kerosene (350 ppm Sulfur)	N/A	All 4,400 Urban Transit Buses Operated by NYC MTA	Since 1993	0.05 g/bhp-hr to 0.1 g/bhp-hr	N/A
Golden Gate Transit, San Rafael, CA	Make: Detroit Diesel Model: 6V92 Application: Transit Bus Fuel Type: CARB Diesel	N/A	90 Urban Transit Buses	Since early 1990's	Unknown	N/A
Motorola - Oak Hill Site, Austin, Texas	Make: Caterpillar Model: 3516 Application: Backkup Generator Fuel Type: Diesel DOC: Johnson Matthey	N/A	1	6 Years (Installed April '94)	N/A	Unknown

List of Emission Test Results

Technology Name: Diesel Oxidation Catalyst

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Control Efficiency
8-mode steady-state	Canada Center for Mining and Minerals Technology July 1998	Dieselytic SX Exhaust Gas Purifier Mfg. by: Catalytic Exhaust Products Limited	Make: Deutz Model: F6L-912W Year: 1979 BHP: 75.4 bhp Application: Underground mining Configuration: Naturally aspirated Engine Hours: Approx. 2,000 hours Fuel Type: 250 ppm Sulfur Diesel Fuel Use: 31.9 lb/hr Exhaust Temp: 146°F - 880°F	PM NOx CO HC	100.6 mg/m^3 835.3 ppm 291.2 ppm 130.1 ppm	84.9 mg/m^3 835.0 ppm 118.9 ppm 79.5 ppm	16% 0% 59% 39%
ISO 8178-D2 5-mode steady-state	Not Publicly Available[12]	Nett DH422 Diesel Purifier Mfg. by: Nett Technologies	Make: Ford Model: 5.0 liter Year: Unknown BHP: 150 Application: Generator Configuration: Unknown Engine Hours: Unknown Fuel Type: Diesel Fuel Use: Unknown Exhaust Temp: 933˚F	PM NOx CO HC	0.5656 g/bhp-hr 6.468 g/bhp-hr 1.108 g/bhp-hr 0.489 g/bhp-hr	0.4475 g/bhp-hr 6.429 g/bhp-hr 0.214 g/bhp-hr 0.067 g/bhp-hr	21% 1% 81% 86%

[12] The manufacturer has requested that the name of the company that performed the emission tests be withheld from publication.

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Control Efficiency
ISO 8178-D2 5-mode steady-state	Not Publicly Available[13]	Nett DH312 Diesel Purifier Mfg. by: Nett Technologies Inc.	Make: Ford Model: 5.0 liter Year: Unknown BHP: 150 Application: Generator Configuration: Unknown Engine Hours: Unknown Fuel Use: Unknown Exhaust Temp: 948˚F	PM NOx CO HC	0.5656 g/bhp-hr 6.468 g/bhp-hr 1.108 g/bhp-hr 0.489 g/bhp-hr	0.521 g/bhp-hr 6.943 g/bhp-hr 0.245 g/bhp-hr 0.121 g/bhp-hr	8% -7% 78% 75%
Transient cycle designed for a specific bulldozer application.[14]	Emissions Research and Measurement Division, Environment Canada	PTX Oxidation Catalyst Mfg. by: Engelhard Corporation	Make: Cummins Model: TD-25G Year: Unknown BHP: 450 Application: Bulldozer Configuration: Unknown Engine Hours: Unknown Fuel Type: 530 ppm S Diesel Fuel Use: 34.36 kg/hr Exhaust Temp: Unknown	PM NOx CO HC	62.54 g/hr 871.03 g/hr 302.37 g/hr 42.95 g/hr	47.40 g/hr 886.60 g/hr 214.15 g/hr 43.31 g/hr	24% -2% 29% -1%
Federal Test Procedure	Engine Research Center, Department of Mechanical & Aerospace Engineering, West Virginia University	CMX Diesel Oxidation Catalyst Mfg. by: Engelhard Corporation	Make: Cummins Model: L-10 Year: 1992 BHP: 280 Application: Urban Bus Configuration: Electronic Controls Engine Hours: Unknown Fuel Type: Diesel - 500 ppm S max Fuel Use (lb/bhp-hr): 0.373 / 0.368 Exhaust Temp: Unknown	PM NOx CO HC	0.105 g/bhp-hr 5.045 g/bhp-hr 1.467 g/bhp-hr 0.260 g/bhp-hr	0.073 g/bhp-hr 4.874 g/bhp-hr 0.759 g/bhp-hr 0.127 g/bhp-hr	30% 3% 48% 51%

[13] The manufacturer has requested that the name of the company that performed the emission tests be withheld from publication.

[14] Study reported in SAE Technical Paper # 1999-01-0110 entitled “The Impact of Retrofit Exhaust Control Technologies on Emissions from Heavy-Duty Diesel Construction Equipment.”

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Control Efficiency
Federal Test Procedure[15]	Southwest Research Institute, Inc.	Five Individual Diesel Oxidation Catalysts	Make: Detroit Diesel Corporation Model: DDC 6067TK60 (DDC Series 60) Year:1998 BHP: 400 hp Application: Heavy Duty Vehicle Configuration: Turbocharged & Aftercooled Engine Hours: Not Reported Fuel Type: 368 ppm S Diesel Fuel Use (lb/bhp-hr): 0.395 - 0.406 Exhaust Temp: Approx 100-800˚F			DOC "A"	
				PM	0.073 g/bhp-hr	0.056 g/bhp-hr	23%
				NOx	3.991 g/bhp-hr	3.995 g/bhp-hr	0%
				CO	1.111 g/bhp-hr	0.674 g/bhp-hr	39%
				HC	0.115 g/bhp-hr	0.050 g/bhp-hr	57%
						DOC "B"	
				PM		0.055 g/bhp-hr	25%
				NOx		4.085 g/bhp-hr	-2%
				CO		0.350 g/bhp-hr	68%
				HC		0.014 g/bhp-hr	88%
						DOC "C"	
				PM		0.069 g/bhp-hr	5%
				NOx		4.034 g/bhp-hr	-1%
				CO		0.202 g/bhp-hr	82%
				HC		0.003 g/bhp-hr	97%
						DOC "D"	
				PM		0.052 g/bhp-hr	29%
				NOx		3.996 g/bhp-hr	0%
				CO		0.964 g/bhp-hr	13%
				HC		0.055 g/bhp-hr	52%
						DOC "E"	
				PM		0.053 g/bhp-hr	27%
				NOx		3.922 g/bhp-hr	2%
				CO		0.479 g/bhp-hr	57%
				HC		0.014 g/bhp-hr	88%

[15] The FTP emission test information was presented in the May 1999 report "Demonstration of Advanced Emission Control Technologies Enabling Diesel-Powered Heavy-Duty Engines to Achieve Very Low Emission Levels" prepared for the Manufacturers of Emission Controls Association by Southwest Research Institute, Inc.

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Control Efficiency
Federal Test Procedure[16]	Southwest Research Institute, Inc.	One Individual Diesel Oxidation Catalysts	Make: Detroit Diesel Corporation Model: DDC 6067TK60 (DDC Series 60) Year:1998 BHP: 400 hp Application: Heavy Duty Vehicle Configuration: Turbocharged & Aftercooled Engine Hours: Not Reported Fuel Type: 368 ppm S Diesel Fuel Use (lb/bhp-hr): 0.401 - 0.403 Exhaust Temp: Approx 100-800˚F		None	DOC "F"	
				PM	0.073 g/bhp-hr	0.077 g/bhp-hr	-5%
				NOx	3.991 g/bhp-hr	4.004 g/bhp-hr	0%
				CO	1.111 g/bhp-hr	0.260 g/bhp-hr	77%
				HC	0.115 g/bhp-hr	0.004 g/bhp-hr	97%
Federal Test Procedure [16]	Southwest Research Institute, Inc.	Three Individual Diesel Oxidation Catalysts	Make: Detroit Diesel Corporation Model: DDC 6067TK60 (DDC Series 60) Year:1998 BHP: 400 hp Application: Heavy Duty Vehicle Configuration: Turbocharged & Aftercooled Engine Hours: Not Reported Fuel Type: 54 ppm S Diesel Fuel Use (lb/bhp-hr): 0.397 - 0.403 Exhaust Temp: Approx 100-800˚F			DOC "B"	
				PM	0.063 g/bhp-hr	0.043 g/bhp-hr	32%
				NOx	3.836 g/bhp-hr	3.941 g/bhp-hr	-3%
				CO	1.200 g/bhp-hr	0.347 g/bhp-hr	71%
				HC	0.109 g/bhp-hr	0.032 g/bhp-hr	71%
						DOC "E"	
				PM		0.046 g/bhp-hr	27%
				NOx		3.781 g/bhp-hr	1%
				CO		0.522 g/bhp-hr	57%
				HC		0.041 g/bhp-hr	62%
						DOC "F"	
				PM		0.053 g/bhp-hr	16%
				NOx		3.961 g/bhp-hr	-3%
				CO		0.194 g/bhp-hr	84%
				HC		0.016 g/bhp-hr	85%

[16] The FTP emission test information was presented in the May 1999 report "Demonstration of Advanced Emission Control Technologies Enabling Diesel-Powered Heavy-Duty Engines to Achieve Very Low Emission Levels" prepared for the Manufacturers of Emission Controls Association by Southwest Research Institute, Inc.

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Control Efficiency
Federal Test Procedure	Southwest Research Institute, Inc.[17]	Catalytic Exhaust Muffler (CEM) Mfg. by Johnson Matthey, Inc.	Make: Detroit Diesel Corporation Model: 6V92TA MUI Year:1986 BHP: Not Reported Application: Heavy Duty Vehicle Configuration: Not Reported Engine Miles: 300,000 Fuel Type: Diesel Fuel Use (lb/bhp-hr): Not Reported Exhaust Temp: Not Reported	PM NOx CO HC	0.443 g/bhp-hr 10.458 g/bhp-hr 1.007 g/bhp-hr 0.694 g/bhp-hr	0.218 g/bhp-hr 10.194 g/bhp-hr 0.607 g/bhp-hr 0.370 g/bhp-hr	51% 3% 40% 47%

[17] The emission test information was submitted to support Johnson Matthey's application for exemption from the State's emission control system anti-tampering law, Vehicle Code section 27156.

DRAFT Control Technology Evaluation

Item	Response
Product Name:	ECOTIP Superstack Fuel Injectors
Product Vendor:	Interstate Diesel
Vendor Address:	4901 Lakeside Avenue Cleveland, OH 44114
Product Description: (What is the product, and how does it work?)	The product consists of a fuel injector with a reduced sac volume and a more consistent fuel injection pressure. The product improves combustion and reduces particulate emissions by minimizing the amount of fuel that drips into the combustion chamber at the end of the chamber's fuel injection cycle.
Applicability: (What types of engines can the product be installed on?)	The product is available for diesel-fueled engines manufactured by General Motors Electro-Motive Division (EMD) and Detroit Diesel Corporation (DDC). The product can be incorporated into either mechanical or electronic fuel injection systems. For EMD engines, mechanical fuel injectors are available as OEM products and electronic fuel injectors are available as replacement products. For DDC engines, both mechanical and electronic fuel injectors are available as replacement products.
Emission Reduction Claim: (What level of emission reduction can be achieved? Address: EC, SOF, and SO_3?)	The manufacturer states that the overall particulate removal efficiency can be as high as 44% for EMD engines and as high as 7% for DDC engines. The manufacturer guarantees the emission reductions within standard testing errors.
Achieved Emission Reductions:	**Product** / **Test Cycle** / **PM Reduction** ECOTIP Standard / 8-Mode Steady State / 7% ECOTIP 2° ITR / 8-Mode Steady State / 3%
Certifications:	None.
Product Costs: **Initial Retail:**	The initial cost range for standard stationary and portable applications, assuming core exchange, is: $200 for a 100 hp engine; $200 - $300 for a 275 hp engine; $300 - $400 for a 400 hp engine; and $400 - $800 for a 1,400 hp engine. These costs may be higher for special applications.
Installation:	No installation costs beyond those associated with replacing standard fuel injectors.
Operating:	Fuel economy is reported to improve by 2% to 3%;
Maintenance:	None.
Durability / Product Life: (How long can the product be expected to function under normal operating conditions and still achieve the specified emission reductions?)	The manufacturer states that the product's useful life is typically between 4,000 and 6,000 service hours under normal operating conditions.

Item	Response
Product Warranty: (Identify the type of warranty and its duration.)	The manufacturer provides a 12 month / 2,000 engine hour warranty.
Affect on Engine Warranty: (When possible, identify any impact the product may have on an engine's warranty.)	When installed as an OEM component of EMD engines, the product does not impact the OEM engine warranty. When installed on DDC engines, use of the product may affect the OEM engine warranty if the product is determined to be the cause of a failure.
Adverse Impacts: **Environmental:** **Safety:**	One 8-mode steady-state emission test shows that the product increases hydrocarbon emissions by 15%. No known adverse safety impacts.
Special Operating Requirements: (e.g. ultra-low sulfur fuel or minimum exhaust temperature, etc...)	The product can be used with the existing California diesel fuel formulations.
Current Status: (Is the product commercially available, or is it still under development? How many engines has the product been installed on, and how long has the product been in use?)	The product is commercially available and has been installed on approximately 2,000 mostly locomotive diesel-fueled engines. The product has been in service in the locomotive market since 1995.
Other: (e.g. fuel penalty, reduced product life, weight, affect on engine performance, etc...)	Fuel economy is reported to improve by 2% to 3%. In addition, the product reduces carbon monoxide and oxides of nitrogen emissions.
Impacts of Lower Sulfur Diesel Fuel:	Unknown. However, the product can be used with the existing California diesel fuel formulations.
Comments: (Address other issues relevant to the use of this product, including other advantages / disadvantages of using the product.)	According to the manufacturer, particulate matter emissions from fuel injectors can increase over time. As such, the manufacturer anticipates that the particulate matter emission rate may increase over the life of the product but that this increase will be consistent with that of standard fuel injectors.

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List of Stationary &/or Portable Applications

Product Name: ECOTIP Superstack Fuel Injectors

Facility / Operator	Engine Information	Permit / Registration	Number of Applications	Time in Service	PM Emission Limit	PM Emission Test Results
Information on the stationary &/or portable applications of this product is not known.	Make: Model: Application: Fuel Type:					

List of Emission Test Results

Product Name: ECOTIP Superstack Fuel Injectors

Method & Type of Test	Source Test Company	Engine Information	Pollutant	Baseline Emission Rate	Emission Rate w/ Controls	Control Efficiency
ISO 8178 8-mode steady-state	Southwest Research Institute July 1998	Make: Detroit Diesel Model: 4L-71N Year: Unknown BHP: 140 bhp Application: Unknown Configuration: Standard Timing Engine Hours: Unknown Fuel Use (lb/hp-hr)[18]: 0.440 / 0.432 Fuel Type: Diesel Exhaust Temp: Unknown	 PM NOx CO HC	<u>Standard Timing</u> 0.357 g/hp-hr* 18.26 g/hp-hr* 11.30 g/hp-hr* 0.66 g/hp-hr* * Average of three test runs.	<u>Standard Timing</u> 0.331 g/hp-hr* 17.45 g/hp-hr* 9.13 g/hp-hr* 0.76 g/hp-hr* * Average of three test runs.	 7% 4% 19% -15%
ISO 8178 8-mode steady-state	Southwest Research Institute July 1998	Make: Detroit Diesel Model: 4L-71N Year: Unknown BHP: 140 bhp Application: Unknown Configuration: 2˚ Timing Retard Engine Hours: Unknown Fuel Use (lb/hp-hr)[1]: 0.440 / 0.430 Fuel Type: Diesel Exhaust Temp: Unknown	 PM NOx CO HC	<u>Standard Timing</u> 0.357 g/hp-hr* 18.26 g/hp-hr* 11.30 g/hp-hr* 0.66 g/hp-hr* * Average of three test runs.	<u>2˚ Timing Retard</u> 0.347 g/hp-hr* 15.41 g/hp-hr* 9.88 g/hp-hr* 0.66 g/hp-hr* * Average of three test runs.	 3% 16% 13% 0%

[18] Baseline / Retrofit

DRAFT Control Technology Evaluation

Item	Response
Product Name:	Cam Shaft Cylinder Reengineering Kit (Version I and Version II)
Product Vendor:	Clean Cam Technology Systems
Vendor Address:	7001 Charity Avenue Bakersfield, CA 93308
Product Description: (What is the product, and how does it work?)	The products consist of specific engine retrofit components, including a proprietary cam shaft. The products reduce NOx emissions by increasing the volume of exhaust gas that remains in the combustion chamber after the power stroke. Within the combustion chamber, the residual exhaust gas absorbs heat and reduces the peak combustion temperature which results in lower NOx emissions. The injection timing can then be adjusted (i.e. advanced) to maximize particulate emission reductions, or it can be varied to achieve the desired balance of NOx vs. PM. In addition to Version I components, Version II includes modified pistons which allow the piston to remain near top dead center (TDC) for a longer duration.
Applicability: (What types of engines can the product be installed on?)	Version I of the product can be used on all Series 71 and Series 92 diesel-fueled engines manufactured by Detroit Diesel Corporation (DDC). Version II of the product can be used on all Series 92 DDC engines.
Manufacturer's Emission Reduction Claim: (What level of emission reduction can be achieved? Address: EC, SOF, and SO_3?)	The manufacturer states that engines retrofitted with Version I will have emissions of no greater than 1.0 g/bhp-hr of hydrocarbons, 8.5 g/bhp-hr of carbon monoxide, 5.8 g/bhp-hr of nitrogen oxides and 0.16 g/bhp-hr of diesel particulate matter. The manufacturer also states that engines retrofitted with Version II will have emissions of no greater than 0.3 g/bhp-hr of hydrocarbons, 2.6 g/bhp-hr of carbon monoxide, 4.5 g/bhp-hr of nitrogen oxides and 0.15 g/bhp-hr of diesel particulate matter.
Certifications: (Identify certifications the product has received, and explain any limits on the certifications.)	ARB staff have verified the Version I performance claims for eleven models of two-stroke diesel-fueled engines manufactured by DDC before 1993, including: DDC 6V92; 8V92, 12V92, 16V92, 3L71, 4L71, 6L71, 6V71, 8V71, 12V71 & 16V71 engines. ARB staff have also verified the Version II performance claims for four models of two-stroke DDC engines manufactured before 1993, including: DDC 6V92; 8V92, 12V92 & 16V92 engines.
Emission Test Results: (Summarize emission test results and describe in detail on the attached table.)	8-mode steady-state emission test data demonstrate that engines retrofitted with the products can meet the emission limits specified above.

Item	Response
Product Costs: **Initial:**	The incremental cost of the products vary with engine size and are approximately: $1,500 for a 100 hp engine; $1,500 - $2,300 for a 275 hp engine; $1,800 - $3,000 for a 400 hp engine; and $3,000 - $6,000 for a 1,400 hp engine. These costs must be added to the costs of standard rebuild components to determine the total initial cost of the products.
Standard Rebuild	The costs of standard engine rebuild components also vary by engine size and are approximately: $2,500 for a 100 hp engine; $2,500 - $3,800 for a 275 hp engine; $3,000 - $4,500 for a 400 hp engine; and $4,500 - $10,000 for a 1,400 hp engine.
Installation:	There are no installation costs beyond those associated with a standard engine rebuild.
Operating:	Engines retrofitted with the products may incur a fuel penalty of between zero and 12% depending on the engine model and rebuild configuration.
Maintenance:	No additional engine maintenance is required.
Durability / Product Life: (How long can the product be expected to function under normal operating conditions and still achieve the specified emission reductions?)	The manufacturer states that the useful life of the products is between 3,000 and 8,000 operating hours, and that the useful life is consistent with the durability requirements for new nonroad engines. Deterioration factor emission tests demonstrate conformance with the emission performance claim.
Product Warranty: (Identify the type of warranty and its duration.)	The manufacturer provides an emissions / mechanical durability warranty for one year or 3,000 engine hours, whichever occurs first.
Affect on Engine Warranty: (When possible, identify any impact the product may have on an engine's warranty.)	According to the manufacturer, use of the product does not impact the OEM engine warranty.
Adverse Impacts: (For example, does the product create a hazardous byproduct? Attach MSDS sheet if applicable.) **Environmental:** **Safety:**	 The products can also reduce NOx emissions. No known adverse safety impacts.
Special Operating Requirements: (e.g. ultra-low sulfur fuel or minimum exhaust temperature, etc...)	The products can be used with the existing California diesel fuel formulations.

Item	Response
Current Status: (Is the product commercially available, or is it still under development? How many engines has the product been installed on, and how long has the product been in use?)	The products are commercially available and have been installed on approximately 300 stationary and portable diesel-fueled engines, including generators and pumps. The products have also been installed on approximately 1,250 mobile diesel-fueled engines as part of the federal Urban Bus Retrofit program, and they have been installed in military equipment, such as generators, loaders and hydraulic power units. Twenty-five engines retrofitted with the product have logged 20,000+ hours of operation.
Other: (e.g. fuel penalty, reduced product life, weight, affect on engine performance, etc...)	Engines retrofitted with the products may incur a fuel penalty of between zero and 12% depending on the engine model and rebuild configuration.
Comments: (Address other issues relevant to the use of this product, including other advantages / disadvantages of using the product.)	The products are specifically designed to allow older 2-stroke DDC engines to meet State & federal new nonroad engine emission standards.

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List of Stationary &/or Portable Applications

Product Name: CCTS Cam Shaft Cylinder Reengineering Kit (Version I)

Facility / Operator	Engine Information	Permit / Registration	Number of Applications	Time in Service	PM Emission Limit	PM Emission Test Results
Gary Drilling Co. 7001 Charity Ave Bakersfield, CA 93308	Make: Detroit Diesel Model: 4L71T Application: Generators Fuel Type: CARB Diesel	PERP Registration Nos. - 100223 - 100295	2	Since: - 12/16/98 - 11/27/97	0.16 g/bhp-hr	See following table.
Gary Drilling Co. 7001 Charity Ave Bakersfield, CA 93308	Make: Detroit Diesel Model: 8V92TA Application: Pumps Fuel Type: CARB Diesel	PERP Registration Nos. - 100124 - 100222	2	Since: - 11/27/97 - 1/28/99	0.16 g/bhp-hr	See following table.

List of Emission Test Results

Product Name: CCTS Cam Shaft Cylinder Reengineering Kit

Method & Type of Test	Source Test Company	Engine Information	Engine Hours	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Emission Reduction
ISO 8178-C1 40 CFR 89 8-mode steady-state	Southwest Research Institute	Make: Detroit Diesel Corp Model: 6V-92TA Year: 1984 BHP: 310 hp Application: Not Reported Configuration: Turbo Fuel Type: 2-D Diesel Fuel Use[19](lb/hp-hr): 0.414/0.431/0.422/0.425 Exhaust Temp: 329˚F - 697˚F	Zero	PM NOx CO HC	0.299 g/bhp-hr 8.99 g/bhp-hr 0.88 g/bhp-hr 0.51 g/bhp-hr	0.099 g/bhp-hr[20] 4.52 g/bhp-hr[20] 0.5 g/bhp-hr[20] 0.32 g/bhp-hr[20]	67% 50% 43% 37%
			125	PM NOx CO HC	n/a	0.094 g/bhp-hr[21] 5.77 g/bhp-hr[21] 0.39 g/bhp-hr[21] 0.33 g/bhp-hr[21]	69% 36% 56% 35%
			1000	PM NOx CO HC	n/a	0.114 g/bhp-hr[21] 5.15 g/bhp-hr[21] 0.45 g/bhp-hr[21] 0.31 g/bhp-hr[21]	62% 43% 49% 39%

[19] Pre-/Post- Retrofit

[20] Version II

[21] Version I

Method & Type of Test	Source Test Company	Engine Information	Engine Hours	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Emission Reduction
ISO 8178-C1 40 CFR 89 8-mode steady-state	Southwest Research Institute	Make: Detroit Diesel Corp Model: 6V-71TA Year: 1983 BHP: 250 Application: Not Reported Configuration: Turbo, Aftercooled Fuel Type: 2-D Diesel Fuel Use[1] (lb/hp-hr): 0.384/0.430/0.419 Exhaust Temp: 252˚F - 798˚F	Zero	PM NOx CO HC	0.201 g/bhp-hr 10.39 g/bhp-hr 1.2 g/bhp-hr 0.45 g/bhp-hr	0.098 g/bhp-hr[21] 5.26 g/bhp-hr[21] 0.7 g/bhp-hr[21] 0.36 g/bhp-hr[21]	51% 49% 42% 20%
			Zero	PM NOx CO HC	n/a	0.148 g/bhp-hr[21] 5.45 g/bhp-hr[21] 1.16 g/bhp-hr[21] 0.38 g/bhp-hr[21]	26% 48% 3% 16%

Method & Type of Test	Source Test Company	Engine Information	Engine Hours	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Emission Reduction
ISO 8178-C1 40 CFR 89 8-mode steady-state	Southwest Research Institute	Make: Detroit Diesel Corp Model: 6L-71T Year: 1983 BHP: 250 Application: Not Reported Configuration: Turbo Fuel Type: 2-D Diesel Fuel Use[1] (lb/hp-hr): 0.399/0.438/0.450/0.449 Exhaust Temp: 270˚F - 806˚F	Zero	PM NOx CO HC	0.208 g/bhp-hr 12.58 g/bhp-hr 2.00 g/bhp-hr 0.47 g/bhp-hr	n/a	n/a
			125	PM NOx CO HC	n/a	0.151 g/bhp-hr[22] 5.56 g/bhp-hr[22] 0.62 g/bhp-hr[22] 0.48 g/bhp-hr[22]	25% 56% 69% -2%
			279	PM NOx CO HC	n/a	0.143 g/bhp-hr[22] 5.57 g/bhp-hr[22] 0.64 g/bhp-hr[22] 0.42 g/bhp-hr[22]	29% 56% 68% 11%
			500	PM NOx CO HC	n/a	0.147 g/bhp-hr[22] 5.54 g/bhp-hr[22] 0.59 g/bhp-hr[22] 0.39 g/bhp-hr[22]	27% 56% 71% 17%
ISO 8178-D2 40 CFR 89 5-mode steady-state	Southwest Research Institute	Make: Detroit Diesel Corp Model: 4L-71 Year: Unknown BHP: 150 hp Application: Generator Configuration: Turbo Fuel Type: Jet A Fuel Use[1] (lb/hp-hr): 0.481/0.480 Exhaust Temp:365˚F - 971˚F	Not Known	PM NOx CO HC	0.282 g/bhp-hr 18.74 g/bhp-hr 1.40 g/bhp-hr 0.90 g/bhp-hr DDC 4L-71N S/N: 4A246627	0.147 g/bhp-hr[22] 4.44 g/bhp-hr[22] 0.83 g/bhp-hr[22] 0.51 g/bhp-hr[22] DDC 4L-71T S/N: 4A26-8418	48% 76% 41% 43%

[22] Version I

DRAFT Control Technology Evaluation

Item	Response
Product Name:	NOxTECH Emission Control System
Product Vendor:	NOxTECH, Inc.
Vendor Address:	1939 Deere Ave. Irvine, CA 92606
Product Description: (What is the product, and how does it work?)	The product is a muffler-size reactor that reduces carbon monoxide, hydrocarbons, and diesel particulate matter through non-catalytic oxidation, similar to an afterburner. The engine exhaust is heated to between 1,400 to 1,550 °F in the reactor by introducing fuel to the exhaust stream. The high temperature environment oxidizes the diesel particulate matter, carbon monoxide, and hydrocarbon emissions. A urea injection system can be added for reduction of NOx emissions. Systems for engines operating over 2,000 hours per year include a heat exchanger that uses the reactor effluent to preheat the engine exhaust to enhance fuel autoignition.
Applicability: (What types of engines can the product be installed on?)	The product is available for use on stationary and portable internal combustion engines.
Manufacturer's Emission Reduction Claim: (What level of emission reduction can be achieved? Address: EC, SOF, and SO_3?)	90% to 95% NOx reduction. 50% to 90% CO reduction (depending on operating conditions). 50% to 90% Diesel PM reduction (depending on operating conditions). 60% to 95% ROG reduction (depending on operating conditions).
Certifications:	None.
Emission Test Results: (Summarize emission test results and describe in detail on the attached table.)	Engine — Test Method — PM Reduction EMD 16-567-D4 — SCAQMD Method 5.2 — 51% EMD 16-710G4B — SCAQMD Method 5.2 — 62%
Product Costs: **Initial:**	Without urea injection: $400-$1,200 for a 40 hp engine; $1,000-$3,000 for a 100 hp engine; $2,750-$8,250 for a 275 hp engine; $4,000-$12,000 for a 400 hp engine; $14,000-$42,000 for a 1,400 hp engine With urea injection: $600-$1,480 for a 40 hp engine; $1,500-$3,700 for a 100 hp engine; $4125-$10,175 for a 275 hp engine; $6,000-$14,800 for a 400 hp engine; $21,000-$51,800 for a 1,400 hp engine With urea injection and heat exchanger: $2,080-$3,000 for a 40 hp engine; $5,200-$7,500 for a 100 hp engine; $14,300-$20,625 for a 275 hp engine; $20,800-$30,000 for a 400 hp engine; $72,800-$105,000 for a 1,400 hp engine
Installation:	$6,400 - $14,400 (Assuming 2 - 3 weeks x 40 hours/week x $80 - $120/hour).

Item	Response
Product Costs: continued **Operating:**	Fuel penalty of 5% to 8%*. With urea injection system, $300/ton NOx reduced. *The attached summary of emission test results indicates a fuel penalty of 23%-24%. The manufacturer states that this system at Catalina Island is an older model using cyanuric acid. The 5%-8% fuel penalty refers to the new design using liquid urea, which is smaller and more compact.
Maintenance:	Manufacturer estimates maintenance costs will be minimal.
Durability / Product Life: (How long can the product be expected to function under normal operating conditions and still achieve the specified emission reductions?)	The manufacturer suggests that the product's useful life will be similar to that of the associated diesel engine.
Product Warranty: (Identify the type of warranty and its duration.)	The product carries a 12-month warranty. The product is guaranteed to be free from defects in material and workmanship and to maintain emissions compliance during normal operations.
Affect on Engine Warranty: (When possible, identify any impact the product may have on an engine's warranty.)	The manufacturer states that the product has no impact on the OEM engine warranty.
Adverse Impacts: (For example, does the product create a hazardous byproduct? Attach MSDS sheet if applicable.) **Environmental:**	Where a urea injection system is utilized to reduce NOx, any unreacted urea will be emitted as ammonia. Ammonia is not a federal hazardous air pollutant or a State identified toxic air contaminant. However, ammonia does have acute and chronic non-cancer health effects. Source tests have shown ammonia slip levels controlled to below 2 ppm.
Safety:	No known adverse safety impacts.
Special Operating Requirements: (e.g. ultra-low sulfur fuel or minimum exhaust temperature, etc...)	None.
Current Status: (Is the product commercially available, or is it still under development. How many engines has the product been installed on, and how long has the product been in use?)	The product is commercially available and has been installed on two stationary diesel generator sets that provide primary commercial power for Catalina Island. One installation has been in operation for 3.5 years.

Item	Response
Other: (e.g. fuel penalty, reduced product life, weight, affect on engine performance, etc...)	When the product is used without a heat exchanger, the fuel penalty depends on the engine exhaust temperature. The manufacturer estimates a fuel penalty of 5% to 8%. The size and weight of the product for various engine sizes is approximately 50% larger and heavier than their respective silencers.
Impacts of Lower Sulfur Diesel Fuel:	The product can be used with existing California diesel formulations. The manufacturer states that lower sulfur fuel should have no effect since the product can operate at higher sulfur levels in present fuels.
Comments: (Address other issues relevant to the use of this product, including other advantages / disadvantages of using the product.)	In addition to reducing diesel particulate matter, the manufacturer states that the product may also reduce carbon monoxide by 50%-90%, hydrocarbons by 60%-95%, and oxides of nitrogen emissions by 90%-95% (with urea injection).

DRAFT - DO NOT CITE OR QUOTE

List of Stationary &/or Portable Applications

Product Name: NOxTECH Emission Control System

Facility / Operator	Engine Information	Permit / Registration	Number of Applications	Time in Service	PM Emission Limit	PM Emission Test Results
Southern California Edison - Pebbly Beach Generating Station (Unit #8)	Make: EMD Model: 16-567-D4 Application: Generator Fuel Type: Diesel	SCAQMD RECLAIM Permit No. 4477; Engine ID No. D2, Control ID No. C27	1	Since:	0.1 gr/dscf	0.0172 gr/dscf
Southern California Edison - Pebbly Beach Generating Station (Unit #15)	Make: EMD Model: 16-710G4B Application: Generator Fuel Type: Diesel	SCAQMD RECLAIM Permit No. 4477; Engine ID No. D42, Control ID No. C43	1	Since: Issued 11/4/94	0.1 gr/dscf	0.006 gr/dscf

List of Emission Test Results

Product Name: NOxTECH Emission Control System

Method & Type of Test	Source Test Company	Engine Information	Engine Hours	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Emission Reduction
PM: SCAQMD Method 5.2 NOx, CO: SCAQMD Method 100.1 HC: SCAQMD Method 25.1	SCEC Test dates: 9/15-17/93	Make: Electro-Motive Diesel (EMD) Model: 16-567-D4 Year: Not reported BHP: 2150 Application: 1.5 MW Generator Configuration: Two-cycle, lean burn with turbocharger Fuel Use (gal/hr): 87.6 (engine) + 21.4 (supplemental) Exhaust Temp (°F): 612 (prior to control device)	Not Reported	PM NOx CO HC	0.510 g/bhp-hr* 11.343 g/bhp-hr* 4.857 g/bhp-hr* 0.133 g/bhp-hr* *Average of 3 runs at low, mid, and high loads	0.251 g/bhp-hr* 1.163 g/bhp-hr* 0.205 g/bhp-hr* 0.034 g/bhp-hr* *Average of 3 runs at low, mid, and high loads	51% 90% 96% 74%
PM: SCAQMD Method 5.2 NOx, CO: SCAQMD Method 100.1 HC: Modified Method 25.2 (Baseline); Method 25.1 (Controlled)	SCEC Test dates: 5/10/95 (baseline) and 1/30-2/1/96 (controlled)	Make: Electro-Motive Diesel Model: 16-710G4B Year: Not reported BHP: 3900 Application: 2.8 MW Generator Configuration: Two-cycle, lean burn with turbocharger and aftercooler Fuel Use (gal/hr): 191.2 (engine) + 44.8 (supplemental) Exhaust Temp (°F): 599 (prior to control device)	Not Reported	PM NOx CO HC	0.215 g/bhp-hr* 6.225 g/bhp-hr*[23] 0.305 g/bhp-hr* 0.360 g/bhp-hr* *Average of 2 runs at high load	0.082 g/bhp-hr* 0.826 g/bhp-hr* 0.321 g/bhp-hr* 0.347 g/bhp-hr* *Average of 2 runs at high load	62% 87% -5%[24] 4%

[23] Engine is equipped with electronically controlled low NOx fuel injectors and the injection timing was retarded during the test.

[24] Manufacturer states that the number is a reflection of the operating requirements of this installation. As a whole, the manufacturer states that the product can reduce CO to below 50 ppm if required.

DRAFT Control Technology Evaluation

Item	Response
Product Name:	Fumigation Natural Gas/Diesel Bi-Fuel Retrofit Kit
Product Vendor:	Innovative Technologies Group, Corp.
Vendor Address:	2968 Ravenswood Road, Unit 109 Ft. Lauderdale, FL 33312
Product Description: (What is the product, and how does it work?)	The product is a bi-fuel conversion system for all diesel-fueled engines, and it involves retrofitting existing diesel-fueled engines to operate on a mixture of diesel fuel and a variety of gaseous fuels, such as pipeline quality natural gas, liquefied natural gas, compressed natural gas, digester gas, etc… The supplemental gaseous fuel is mixed with combustion air before being introduced into the engine's charge air system. This process is referred to as fumigation. Within the combustion chamber, the diesel fuel serves as a pilot ignition source for the gaseous fuel. The gaseous fuel / diesel mixture typically varies between 80% gaseous / 20% diesel to 50% gaseous / 50% diesel. The engine retrofit mainly involves the integration of a gaseous fuel control system with an engine's charge air system. There are no changes to the engine block, cylinder heads, pistons, etc..., and the engine remains a compression ignition engine.
Applicability: (What types of engines can the product be installed on?)	The product can be applied to all diesel-fueled engines, including stationary, portable, mobile, marine, and locomotive engines. The product can also be retrofitted to existing engines.
Manufacturer's Emission Reduction Claim: (What level of emission reduction can be achieved? Address: EC, SOF, and SO_3?)	The manufacturer claims that the product reduces oxides of nitrogen emissions by 20% to 60%. While the manufacturer does not specifically claim that the product reduces diesel particulate emissions, the emission test data suggests that the product reduces diesel particulate by up to 37%.
Certifications: (Identify certifications the product has received, and explain any limits on the certifications.)	The product has been certified as an alternative fuel delivery system in accordance with the provisions of Sections 43004 and 43006 of the California Health and Safety Code for use on 1993 and older model year four-stroke heavy-duty diesel-fueled engines, excluding those equipped with self-compensating fuel pumps.
Emission Test Results: (Summarize emission test results and describe in detail on the attached table.)	**Engine Make/Model** — **Test Cycle** — **PM Reduction** International Harvester 7.3 liter — CVS-75 — 28% Cummins 5.9 liter — CVS-72 — 37%

Item	Response
Product Costs: **Initial / Installation:**	The initial product cost is: $4,000 for a 40 hp engine, $6,000 for a 100 hp engine,$14,000 for a 400 hp engine, and $38,000 for a 1,400 hp engine. These costs do not include installation of gaseous fuel supply systems, which vary by application.
Installation:	Installation is typically performed by the manufacturer, or the manufacturer's representative, and usually takes between four and five days. At the manufacturer's rate of $450 per day, installation costs are expected to be between $1,800 and $2,250, not including travel.
Operating:	The operating costs depend on the specific application and the type of gaseous fuel used. However, a 13% - 14% decrease in fuel costs is expected if an engine operates on a mixture of 40% diesel and 60% natural gas, assuming diesel costs $0.90/gal and natural gas costs $0.50 per therm.
Maintenance:	There are no additional maintenance requirements associated with the use of this product. However, according to the manufacturer, the engine oil will not need to be changed as frequently.
Durability / Product Life: (How long can the product be expected to function under normal operating conditions and still achieve the specified emission reductions?)	According to the manufacturer, the product life is consistent with that of other mechanical engine components.
Product Warranty: (Identify the type of warranty and its duration.)	The manufacturer provides a one year warranty on materials and workmanship which includes repair or replacement of an engine if damage is caused by the bi-fuel system.
Affect on Engine Warranty: (When possible, identify any impact the product may have on an engine's warranty.)	The product manufacturer does not expect the engine manufacturer's warranty to cover damage caused by the bi-fuel process. As noted above, the product manufacturer will repair or replace an engine damaged by the bi-fuel system.
Adverse Impacts: (For example, does the product create a hazardous byproduct? Attach MSDS sheet if applicable.) **Environmental:**	There are no known adverse environmental impacts.
Safety:	There are no known adverse safety impacts.
Special Operating Requirements: (e.g. ultra-low sulfur fuel or minimum exhaust temperature, etc...)	The product requires a gaseous fuel supply system, such as a natural gas supply system for stationary applications or a CNG storage system for portable and/or mobile applications.

Item	Response
Current Status: (Is the product commercially available, or is it still under development? How many engines has the product been installed on, and how long has the product been in use?)	The product is commercially available and has been installed on more than 200 diesel-fueled engines, including stationary generators, trucks, buses, and locomotives.
Other: (e.g. fuel penalty, reduced product life, weight, affect on engine performance, etc...)	According to the manufacturer, engines retrofitted with this technology do not suffer a loss of power.
Impacts of Low Sulfur Fuel	The product can be used with California's existing diesel fuel formulations.
Comments: (Address other issues relevant to the use of this product, including other advantages / disadvantages of using the product.)	Representatives from one facility which operates a 1,490 hp engine equipped with the bi-fuel technology suggest that the product reduces NOx emissions by up to 20 lb/hr and that there is an overall fuel savings because the cost of natural gas is about one third of the cost of diesel fuel.

List of Stationary &/or Portable Applications

Product Name: Fumigation Natural Gas/Diesel Bi-Fuel Retrofit Kit

Facility / Operator	Engine Information	Permit / Registration	Number of Applications	Time in Service	PM Emission Limit	PM Emission Test Results
International Billing Services, El Dorado Hills, California	Make: Cummins Model: KTTA-50-G2 Horsepower: 2200 Application: Generator Fuel Type: Diesel / Natural Gas	Authority to Construct No. 13-903-01, Issued by the El Dorado County Air Pollution Control District on February 28, 2000	1	None	None	N/A
Chicago Landfill, Templeton, CA	Make: Komatsu Model: Unknown Horsepower: 227 hp Application: Generator Fuel Type: Landfill Gas + Low Sulfur Diesel Fuel	Permit to Operate No. 548-1 Issued by the San Luis Obispo County Air Pollution Control District	1	June 1998	None	N/A
Roche Diagnostics Corporation, Indianapolis, IN	Make: Caterpillar Model: 3516 Horsepower: 2615 hp Application: Generator Fuel Type: Diesel & Diesel/Natural Gas	Indianapolis Environmental Resources Management, Federally Enforceable State Operating Permit No. F097-11275-00338 Issued January 12, 2000	4	Units In Service Since December 1993	None	N/A
AFG Industries Victorville, CA	Make: Cummins Model: KTA-50-G1 Horsepower: 1,490 bhp Application: Emergency Backup Generator Fuel Type: Diesel / Natural Gas (40%:60%)	Permit No: E001729 Issued by the Mojave Desert Air Quality Management District	1	Approx. 3 Years	None	N/A

List of Emission Test Results

Product Name: Fumigation Natural Gas/Diesel Bi-Fuel Retrofit Kit

Method & Type of Test	Source Test Company	Engine Information	Test Procedure	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Emission Reduction
Federal Test Procedure[25] (UDDS)	Air Testing Services, Inc. Landsdale, PA	Make: Cummins Model: 5.9 liter Year: 1992 BHP: Not Reported Application: Light Duty Truck Configuration: Not Reported Engine Hours: Not Reported Fuel Use: Not Reported Exhaust Temp: Not Reported	CVS-75		100% Diesel	80% CNG / 20% Diesel	
				PM	0.627 gm/mile	0.436 gm/mile	30%
				NOx	6.444 gm/mile	6.429 gm/mile	0%
				CO	1.830 gm/mile	0.957 gm/mile	48%
				HC	0.908 gm/mile	0.912 gm/mile	0%
			CVS-72 (Hot Start)		100% Diesel	80% CNG / 20% Diesel	
				PM	0.347 gm/mile	0.220 gm/mile	37%
				NOx	6.351 gm/mile	6.135 gm/mile	3%
				CO	1.606 gm/mile	0.658 gm/mile	59%
				HC	0.799 gm/mile	0.563 gm/mile	30%
Federal Test Procedure [25] (UDDS)	Air Testing Services, Inc. Landsdale, PA	Make: International Harvester Model: 7.3 liter Year: 1992 BHP: Not Reported Application: Light Duty Truck Configuration: Not Reported Engine Hours: Not Reported Fuel Use: Not Reported Exhaust Temp: Not Reported	CVS-75		100% Diesel	80% CNG / 20% Diesel	
				PM	0.199 gm/mile	0.144 gm/mile	28%
				NOx	9.151 gm/mile	5.717 gm/mile	38%
				CO	1.149 gm/mile	1.080 gm/mile	6%
				HC	0.560 gm/mile	0.348 gm/mile	38%
			CVS-72 (Hot Start)		100% Diesel	80% CNG / 20% Diesel	
				PM	0.146 gm/mile	0.121 gm/mile	17%
				NOx	7.992 gm/mile	6.683 gm/mile	16%
				CO	0.773 gm/mile	0.764 gm/mile	1%
				HC	0.245 gm/mile	0.167 gm/mile	32%

[25] The emission test results were provided by Carburetion Labs International, Inc. (CLI) in support of their application for certification of an alternative fuel delivery system in accordance with Sections 43004 and 43006 of the California Health and Safety Code. The ARB's Mobile Source Division reviewed the product and associated emission test data, and on December 22, 1992, the ARB issued Executive Order B-17 approving the use of this technology on all 1992 and older model year heavy-duty diesel engines excluding those with self-compensating fuel pumps. The Executive Order has been updated several times, and now applies to all 1993 and older model year four-stroke heavy-duty diesel engines excluding those with self-compensating fuel pumps (EO B-44 & B-44-1). Innovative Technologies Group now owns the rights to this technology.

DRAFT Control Technology Evaluation

Item	Response
Product Name:	SINOx System
Product Vendor:	Siemens Westinghouse Power Corporation
Vendor Address:	1345 Ridgeland Parkway, Suite 116 Alpharetta, GA 30004
Product Description: (What is the product, and how does it work?)	The product is a Selective Catalytic Reduction (SCR) system consisting of a proprietary base metal catalyst, designed specifically for diesel-fueled engines and an integrated predictive emissions monitoring system. According to the manufacturer, the product reduces the volatile organic fraction (VOF) of diesel particulate matter and hydrocarbon/air toxics emissions through catalytic oxidation, and concurrently reduces NOx emissions using a reducing agent, such as a 32% aqueous urea solution. The product also allows the injection timing of non-certified engines to be adjusted for maximum fuel efficiency which may result in further reductions of diesel particulate matter and hydrocarbon/air toxic emissions.
Applicability: (What types of engines can the product be installed on?)	The product can be used on stationary, portable and mobile diesel-fueled engines typically rated at 200 horsepower to 10,000 horsepower or more.
Manufacturer's Emission Reduction Claim: (What level of emission reduction can be achieved? Address: EC, SOF, and SO_3?)	The manufacturer states that the product's overall particulate removal efficiency can be between 20% and 50% depending on the engine timing, the type of controls and the uncontrolled emission rate. In addition, the product's VOF removal efficiency can be more than 60%, hydrocarbon/air toxics removal efficiency can be more than 90%, NOx removal efficiency can be over 90% in stationary and portable applications, and over 65% to 85% in on- and offroad applications.
Certifications: (Identify certifications the product has received, and explain any limits on the certifications.)	
Emission Test Results: (Summarize emission test results and describe in detail on the attached table.)	**Engine Make/Model** — **Test Cycle** — **PM Reduction** 1999 DDC Series 60 — FTP — 28% 1999 Mack E-Tech E7 — Cold Transient — 22% 1999 Mack E-Tech E7 — Hot Transient — 25% 1999 Mack E-Tech E7 — OICA — 0%

Item	Response
Product Costs: **Initial:**	The initial cost of the product depends on the degree of custom engineering required, the size of the engine, the operating conditions and other variables such as production volume, and ranges from approximately $50 to $60 per horsepower. For example, the initial cost typically ranges from $13,750 to $16,500 for a 275 hp engine, $20,000 to $24,000 for a 400 hp engine, and $70,000 to $84,000 for a 1,400 hp engine.
Installation:	Installation costs vary from $500 to $5,000 depending on the application.
Operating:	The operating costs include approximately $300 per ton of NOx reduced for the aqueous urea.
Maintenance:	The maintenance costs vary depending on engine size, run time and other variables. Approximate costs are $715 per year for a 275 hp engine, $800 per year for a 400 hp engine, and $1,500 per year for a 1,400 hp engine.
Durability / Product Life: (How long can the product be expected to function under normal operating conditions and still achieve the specified emission reductions?)	According to the manufacturer, operating periods of greater than 20,000 hours have been demonstrated, and some vehicles have accumulated over 500,000 miles.
Product Warranty: (Identify the type of warranty and its duration.)	The manufacturer provides a one year standard equipment warranty for workmanship, parts and materials. The manufacturer also provides a process guarantee of up to 3 years / 20,000 service hours (whichever occurs first) for the emission reductions in stationary and portable applications.
Affect on Engine Warranty:	According to the manufacturer, use of the product does not impact the OEM engine warranty.
Adverse Impacts: (For example, does the product create a hazardous byproduct? Attach MSDS sheet if applicable.) **Environmental:**	Aqueous urea is used to reduce NOx emissions, and any unreacted urea will be emitted as ammonia (a.k.a. ammonia slip). Although ammonia is not a state toxic air contaminant or federal hazardous air pollutant, ammonia does have acute and chronic non-cancer health effects. Source tests have shown ammonia slip levels controlled to 4.4 ppm averaged over the FTP test cycle, although spikes have reached 30 ppm. The federal OSHA 15-minute short term exposure limit for ammonia is 35 ppm.
	Several FTP transient emission tests show that the product increases carbon monoxide emissions by up to 89%; however, the applicable carbon monoxide emission limits were not exceeded.
Adverse Impacts: **Safety:**	Except as noted previously, there are no other known safety impacts when aqueous urea is used as the reducing agent.
Special Operating Requirements: (e.g. ultra-low sulfur fuel or minimum exhaust temperature, etc...)	The typical engine exhaust temperature range is 350 ˚F to 1,020 ˚F.

<table>
<tr><th>Item</th><th>Response</th></tr>
<tr><td>Current Status:
(Is the product commercially available, or is it still under development? How many engines has the product been installed on, and how long has the product been in use?)</td><td>The product is commercially available for stationary and mobile engines in Europe. In the US, it is commercially available for stationary engines and ready for commercialization for mobile engines. (For mobile applications, commercialization for a specific engine family depends on the development / availability of an emission map for the respective engine family - see the Comments section below.)

The product has been installed on 125 stationary, portable, and mobile diesel-fueled engines worldwide. Specific applications include: stationary and portable generator sets, pump stations, marine vessels, on-highway heavy-duty trucks, offroad construction equipment, and locomotives.</td></tr>
<tr><td>Other:
(e.g. fuel penalty, reduced product life, weight, affect on engine performance, etc...)</td><td>The typical size and weight of demonstration and other stationary SINOx Systems are as follows:
<table><tr><th>HP</th><th>Length</th><th>Width</th><th>Height</th><th>Weight</th></tr><tr><td>275</td><td>14 in</td><td>18 in</td><td>18 in</td><td>150 lb</td></tr><tr><td>400</td><td>14 in</td><td>18 in</td><td>18 in</td><td>150 lb</td></tr><tr><td>1,400</td><td>40 in</td><td>35 in</td><td>35 in</td><td>- - -</td></tr></table></td></tr>
<tr><td>Impacts of Low Sulfur Fuel</td><td>According to manufacturer documentation, the catalyst is formulated for low SO_2/SO_3 conversion (i.e. < 1%). The product is resistant to fuel sulfur and can be used with the existing California diesel fuel formulations, as well as with high sulfur fuels such as bulk or crude oil used in coastal and ocean vessels.</td></tr>
<tr><td>Comments:
(Address other issues relevant to the use of this product, including other advantages / disadvantages of using the product.)</td><td>In mobile applications, the product relies on an open loop control system to regulate urea injection. An emission “map” of each engine family is developed, and a predictive emission monitoring system evaluates multiple engine operating parameters. After comparing these parameters to the emission map, the control system regulates the quantity of urea introduced to the SCR catalyst ensuring optimum NOx reductions with minimal ammonia slip.

According to the manufacturer, volume production of the SINOx system will begin in Europe for model year 2001 Class 8 heavy-duty diesel-fueled trucks (250 - 400 hp). This will allow the design to be standardized for particular engine families.</td></tr>
</table>

List of Stationary &/or Portable Applications

Product Name: SINOx System

Facility / Operator	Engine Information	Permit / Registration	Number of Engines	Time in Service	Emission Limitation	Emission Test Results
Yale University	Make: Mitsubishi Model: S16R-PTA Horsepower: 2,164 hp Application: Generator Fuel Type: Diesel	Permit # 117-0204 Issued by the Connecticut Department of Environmental Protection, Bureau of Air Management	3	Permit Issued 7/1/97	PM: 1.36 lb/hr NO_x: 5.3 lb/hr NH_3: 10 ppm	PM: Unknown NO_x: Unknown NH_3: Unknown
Highway Materials, Inc	Make: Caterpillar Model: 3412C Horsepower: 634 bhp Application: Portable Rock Plant Fuel Type: Not Reported	Plan Approval Permit No. PA-46-0069 Issued by Commonwealth of Pennsylvania, Bureau of Air Quality	2	Plan Approval Issued 5/11/98	PM: 0.33 lb/hr NO_x: 1.7 lb/hr NH_3: 10 ppm	PM: Unknown NO_x: 0.57 lb/hr NH_3: 0.044 ppmvd
	Make: Cummins Model: KTA-50-G3 Horsepower: 1850 bhp Application: Portable Rock Plant Fuel Type: Not Reported				PM: 0.33 lb/hr NO_x: 9.55 lb/hr NH_3: 10 ppm	PM: Unknown NO_x: 2.33 lb/hr NH_3: 0.048 ppmvd

List of Emission Test Results

Product Name: SINOx System

Method & Type of Test	Source Test Company	Engine Information	Engine Hours	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Emission Reduction
Federal Test Procedure	UC Davis, Institute of Transportation Studies	Make: Detroit Diesel Corporation Model: Series 60 Year: 1999 BHP: Not Reported Application: On-highway Heavy Duty Diesel Truck Configuration: Turbocharged & Aftercooled Fuel Type: Certification Diesel Fuel Use: Not reported Exhaust Temp: Not Reported	Not Reported	PM NOx CO HC	0.096 g/bhp-hr[26] 3.761 g/bhp-hr[26] 0.723 g/bhp-hr[26] 0.134 g/bhp-hr[26]	N/A	N/A
			Not Reported	PM NOx CO HC	N/A	0.0693 g/bhp-hr[27] 0.980 g/bhp-hr[27] 1.37 g/bhp-hr[27] 0.0252 g/bhp-hr[27]	28% 74% -89% 81%
Federal Test Procedure (Cold Start & Hot Start)[28]	Southwest Research Institute	Make: Mack Model: E-Tech E7-350 Year: 1999 BHP: 350 bhp Application: Heavy Duty Truck Configuration: Turbocharged and Aftercooled Fuel Type: 2D Diesel Fuel Use: Not Reported Exhaust Temp:	Not Reported	<u>Cold Transient</u> PM NOx CO HC	<u>Cold Transient</u> 0.09 g/bhp-hr 6.24 g/bhp-hr 1.80 g/bhp-hr 0.06 g/bhp-hr	<u>Cold Transient</u> 0.07 g/bhp-hr 2.77 g/bhp-hr 2.31 g/bhp-hr 0.00 g/bhp-hr	 22% 56% -28% 100%
				<u>Hot Transient</u> PM NOx CO HC	<u>Hot Transient</u> 0.08 g/bhp-hr 5.25 g/bhp-hr 1.12 g/bhp-hr 0.06 g/bhp-hr	<u>Hot Transient</u> 0.06 g/bhp-hr 1.55 g/bhp-hr 1.54 g/bhp-hr 0.00 g/bhp-hr	 25% 70% -38% 100%

[26] U.S. EPA On-highway engine certification data.

[27] Emission test results reported in a U.C. Davis study entitled "Urea-SCR System Demonstration and Evaluation for Heavy-Duty Diesel Trucks: Phase I, Preliminary Emissions Test Results and Cost-Effectiveness Analysis."

[28] Emission test results reported in SAE Technical Paper # 2000-01-0190, "The Development of Urea-SCR Technology for US Heavy Duty Trucks."

Method & Type of Test	Source Test Company	Engine Information	Engine Hours	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Emission Reduction
OICA[29]	Southwest Research Institute	Make: Mack Model: E-Tech E7-350 Year: 1999 BHP: 350 bhp Application: Heavy Duty Truck Configuration: Turbocharged and Aftercooled Fuel Type: 2D Diesel Fuel Use: Not Reported Exhaust Temp:	Not Reported	 PM NOx CO HC	OICA 0.04 g/bhp-hr 4.86 g/bhp-hr 0.29 g/bhp-hr 0.01 g/bhp-hr	OICA 0.04 g/bhp-hr 0.70 g/bhp-hr 0.29 g/bhp-hr 0.00 g/bhp-hr	 0% 86% 0% 100%

[29] Emission test results reported in SAE Technical Paper # 2000-01-0190, "The Development of Urea-SCR Technology for US Heavy Duty Trucks."

DRAFT Control Measure Evaluation

Item	Response
Technology:	Repower with Tier 2 or Tier 3 certified nonroad engines.
Technology Description: (How does it work?)	Replacement of existing diesel engines with engines certified to meet U.S. EPA nonroad engine emission standards. The current Tier 2 standards are as follows: **Horsepower** / **Model Year** / **PM Emission Limit** hp < 25 / 2005 / 0.60 g/bhp-hr 25≤ hp < 50 / 2004 / 0.45 g/bhp-hr 50≤ hp < 100 / 2004 / 0.30 g/bhp-hr 100≤ hp < 175 / 2003 / 0.22 g/bhp-hr 175≤ hp < 300 / 2003 / 0.15 g/bhp-hr 300≤ hp < 600 / 2001 / 0.15 g/bhp-hr 600≤ hp≤ 750 / 2002 / 0.15 g/bhp-hr hp > 750 / 2006 / 0.15 g/bhp-hr The ARB recently adopted emission standards comparable to the U.S. EPA Tier 2 standards described above. Tier 3 standards for particulate matter will be established upon completion of a technical feasibility review, which is scheduled for 2001.
Applicability: (What types of engines can the product be installed on?)	This control measure is applicable to all stationary and portable diesel-fueled engines. Currently, engines rated at 175 horsepower or larger and designated for nonroad applications must meet a particulate matter emission standard. By 2004, all engines designated for nonroad applications must meet a particulate matter emission standard. Certified nonroad engines can be used in stationary applications.
Achieved Emission Reductions:	The federal nonroad engine certification data presented below demonstrates that engines are currently available which meet the Tier 2 standards. **Engine Make & Model** / **Model Year** / **PM Emission Rate** Cummins 6CTAA8.3-G1 / 1999 / 0.132 g/bhp-hr Caterpillar 3306 / 1999 / 0.114 g/bhp-hr Daimler-Benz OM 501 LA / 1999 / 0.042 g/bhp-hr Caterpillar 3408 / 2000 / 0.084 g/bhp-hr Komatsu SA6D140E-2 / 2000 / 0.125 g/bhp-hr
Emission Reduction Guarantee:	Within the limitations of the applicable regulations, certified nonroad engines are required to meet the emission standards throughout their useful life. ARB and U.S. EPA in-use testing and recall programs ensure compliance with these requirements.
Costs: **Initial Retail:**	The initial costs of Tier 2 certified engines range from: $4,290 for a 40 hp engine; $6,960 to $18,840 for a 100 hp engine; $12,440 to $32,150 for a 275 hp engine; $23,100 to $48,370 for a 400 hp engine; and $186,890 for a 1,400 hp engine.
Installation:	The installation costs range from: $2,380 for a 40 hp engine; $4,390 for a 100 hp engine; $3,450 to $6,190 for a 275 hp engine; $8,430 for a 400 hp engine; and $23,630 for a 1,400 hp engine.

Item	Response
Operating:	Operating costs should be similar to a comparably rated non-certified engine.
Maintenance:	Engine maintenance requirements should be comparable to the existing engine.
Certifications:	As previously mentioned, the engines must be certified by the U.S. EPA or ARB to meet the applicable nonroad engine emission standard.
Durability: (How long can the technology be expected to function under normal operating conditions and still achieve the specified emission reductions?)	Federal nonroad engine regulations specify that the useful life of certified nonroad engines is at least: 10 years or 8,000 hours (whichever occurs first) for engines rated at or above 50 horsepower; 7 years or 5,000 hours (whichever occurs first) for engines rated at or above 25 horsepower but less than 50 horsepower; 5 years or 3,000 hours (whichever occurs first) for engines rated at less than 25 horsepower; and 5 years or 3,000 hours (whichever occurs first) for constant-speed engines rated at less than 50 horsepower with rated speeds of 3,000 rpm or more. The ARB recently adopted useful life requirements comparable to the federal requirements described above.
Warranty:	Federal nonroad engine regulations specify that the warranty period for certified nonroad engines is at least: 5 years or 3,000 hours (whichever occurs first) for engines rated at or above 25 horsepower; 2 years or 1,500 hours (whichever occurs first) for engines rated at less than 25 horsepower; and 2 years or 1,500 hours (whichever occurs first) for constant-speed engines rated at less than 50 horsepower with rated speeds of 3,000 rpm or more. The ARB recently adopted warranty requirements comparable to the federal requirements described above.
Affect on Engine Warranty: (When possible, identify any impact the technology may have on an engine's warranty.)	N/A
Adverse Impacts:	
Environmental:	No known adverse environmental impacts.
Safety:	No known adverse safety impacts.
Special Operating Requirements: (e.g. ultra-low sulfur fuel or minimum exhaust temperature, etc...)	None
Current Status: (Is the technology commercially available, or is it still under development? How many engines has the technology been installed on, and how long has the technology been in use?)	Engines are currently available which meet the Tier 2 nonroad engine emission standards. All new nonroad engines rated at or above 175 horsepower must meet the current Tier 1 particulate matter standard of 0.4 g/bhp-hr. Tier 2 standards will be phased in over a 5 year period beginning in 2001. Tier 3 standards are expected to be phased in between 2006 and 2008.

Item	Response
Other: (e.g. fuel penalty, reduced product life, weight, affect on engine performance, etc...)	N/A
Impacts of Lower Sulfur Diesel Fuel	Although not required to implement this control measure, the use of ultra-low sulfur fuel should reduce the sulfate fraction of diesel particulate matter.
Comments: (Address other issues relevant to the use of this technology, including other advantages / disadvantages of using the technology.)	The disposition of surplus engines must be addressed.

List of Stationary &/or Portable Applications

Technology Name: Repower With Certified Nonroad Engines

Facility / Operator	Engine Information	Permit / Registration	Number of Applications	Time in Service	PM Emission Limit	PM Emission Test Results
Pool California Energy Services	Make: Caterpillar Model: 3406E DITA Horsepower: 582 hp Application: Generator Fuel Type: CARB Diesel	Statewide Portable Equipment Registration Program Regist. No: 103700	1	1 year	0.4 g/bhp-hr	N/A
Alturdyne Motion Picture Services	Make: John Deere Model: 6081AF Horsepower: 300 hp Application: Generator Fuel Type: CARB Diesel	Statewide Portable Equipment Registration Program Regist. No: 101807	1	2 years	0.4 g/bhp-hr	N/A
Johnson Power Systems	Make: Caterpillar Model: 3406 Horsepower: 519 Application: Unknown Fuel Type: CARB Diesel	Statewide Portable Equipment Registration Program Regist. No: 105006	1	1 year	0.4 g/bhp-hr	N/A
Prime Equipment	Make: Komatsu Model: SA6D108E Horsepower: 217 Application: Generator Fuel Type: CARB Diesel	Statewide Portable Equipment Registration Program Regist. No: 104797	1	1 year	0.4 g/bhp-hr	N/A
Nesco Leasing	Make: Komatsu Model: SA6D125E-2 Horsepower: 345 Application: Generator Fuel Type: CARB Diesel	Statewide Portable Equipment Registration Program Regist. No: 104026	1	2 years	0.4 g/bhp-hr	N/A

List of Emission Test Results

Technology Name: Repower With Certified Nonroad Engines

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Emission Rate w/ Controls	Control Efficiency
ISO 8178-D2 5-mode steady-state	U.S. EPA Nonroad Engine Certification Data	Certified Nonroad Engine	Make: Cummins Model: C8.3, 6CTAA8.3-G1 Year: 1999 BHP: 280 Application: Pump, Compressor, Generator Set, Crane, etc... Configuration: Turbo, Aftercooler Engine Hours: n/a Fuel Type: CARB Diesel Fuel Use: Not Reported Exhaust Temp: Not Reported	PM NOx CO HC	0.132 g/bhp-hr 6.32 g/bhp-hr 0.62 g/bhp-hr 0.45 g/bhp-hr	N/A N/A N/A N/A
ISO 8178-C1 8-mode steady-state	U.S. EPA Nonroad Engine Certification Data	Certified Nonroad Engine	Make: Caterpillar Model: 3306 Year: 1999 BHP: 397 Application: Generator Set, Industrial, Excavator, etc... Configuration: Turbo, Aftercooler Engine Hours: n/a Fuel Type: CARB Diesel Fuel Use: Not Reported Exhaust Temp: Not Reported	PM NOx CO HC	0.114 g/bhp-hr 4.65 g/bhp-hr 1.35 g/bhp-hr 0.19 g/bhp-hr	N/A N/A N/A N/A

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Emission Rate w/ Controls	Control Efficiency
ISO 8178-C1 8-mode steady-state	U.S. EPA Nonroad Engine Certification Data	Certified Nonroad Engine	Make: Daimler-Benz AG Model: OM 501 LA Year: 1999 BHP: 422 Application: Not Reported Configuration: Turbo, Aftercooler Engine Hours: n/a Fuel Type: CARB Diesel Fuel Use: Not Reported Exhaust Temp: Not Reported	PM NOx CO HC	0.042 g/bhp-hr 4.97 g/bhp-hr 0.40 g/bhp-hr 0.15 g/bhp-hr	N/A N/A N/A N/A
ISO 8178-C1 8-mode steady-state	U.S. EPA Nonroad Engine Certification Data	Certified Nonroad Engine	Make: Caterpillar Model: 3408 Year: 2000 BHP: 750 Application: Industrial Configuration: Turbo, Aftercooler Engine Hours: n/a Fuel Type: CARB Diesel Fuel Use: Not Reported Exhaust Temp: Not Reported	PM NOx CO HC	0.084 g/bhp-hr 5.84 g/bhp-hr 0.90 g/bhp-hr 0.07 g/bhp-hr	N/A N/A N/A N/A
ISO 8178-C1 8-mode steady-state	U.S. EPA Nonroad Engine Certification Data	Certified Nonroad Engine	Make: Komatsu Model: SA6D140E-2 Year: 2000 BHP: 375 Application: Generator Set, Dozer Configuration: Turbo, Aftercooler Engine Hours: n/a Fuel Type: CARB Diesel Fuel Use: Not Reported Exhaust Temp: Not Reported	PM NOx CO HC	0.125 g/bhp-hr 5.722 g/bhp-hr 0.321 g/bhp-hr 0.221 g/bhp-hr	N/A N/A N/A N/A

DRAFT Control Technology Evaluation

Item	Response
Product Name:	Unikat Combifilter
Product Vendor:	Engine Control Systems
Vendor Address:	165 Pony Drive Newmarket, Ontario Canada, L3Y 7V1
Product Description: (How does it work?)	The product is a diesel particulate filter system which incorporates electrical regeneration. Typically, the particulate filter media consists of either a ceramic wall-flow monolith (e.g. cordierite or silicon carbide) or woven ceramic fibers. The ceramic wall-flow monoliths capture diesel particulate matter primarily through surface filtration, and the woven ceramic fibers capture diesel particulate matter though depth filtration. To prevent plugging of the filter media and to minimize system backpressure, particulate filters must be periodically cleaned. This process of cleaning a particulate filter, termed regeneration, involves the oxidation of the collected particulate matter. Where passive particulate filter systems incorporate catalyst material to lower the temperature at which the collected particulate matter oxidizes, this technology actively regenerates the particulate filter via an electrical heating element. The regeneration is electronically controlled and can be completed in either 30 minutes or 8 hours, depending upon the system chosen.
Applicability: (What types of engines can the product be installed on?)	Individual particulate filter systems are available for diesel-fueled engines rated at between 25 and approximately 200 horsepower. Multiple filter elements can be used together for larger applications.
Achieved Emission Reductions:	**Product** / **Test Cycle** / **PM Reduction** Unikat Combifilter / Special Transient / 81% Unikat Combifilter with oxidation catalyst / ISO 8178 / 95%
Emission Reduction Guarantee:	The manufacturer guarantees that their product will reduce diesel PM emissions by at least 80%.
Costs: **Initial Retail:**	The initial cost is approximately: $4,450 for a 40 hp engine; $5,780 for a 100 hp engine; $11,690 for a 275 hp engine; $14,000 for a 400 hp engine; and $40,250 for a 1,400 hp engine.
Installation:	For single and dual filter systems: $206 - $518 (Assuming 2 - 6 hours x $78/hr + $50 in misc parts.)
Operating:	For a generator larger than 275 hp, the cost to regenerate the filter is about 1% of the energy produced. The regeneration cost is higher for smaller engine generator sets--up to 7% for a 40 hp engine. In addition, fuel consumption may increase by one to one and a half percent due to additional backpressure.

Item	Response
Maintenance:	$312 for prime engine (Assume 2 cleanings at 2 hours labor each— total of 4 hours labor per year.) and $156 for emergency backup engine every five years (Assume 2 hours labor).
Comments:	The particulate filter systems must be cleaned every 1,000 - 1,500 hours of service to remove accumulated ash. The exact interval is dependent on lube oil consumption.
Certifications:	**Product** / **Certification** / **Agency** Unikat Combifilter / 80% diesel PM Removal / Swiss VERT Program Unikat Combifilter / 80% diesel PM Removal / Sweden Environmental Zones--Off-road
Durability / Product Life: (How long can the technology be expected to function under normal operating conditions and still achieve the specified emission reductions?)	Some installations have been in operation over 20,000 hours. The manufacturer does not provide a guarantee for product life.
Product Warranty:	The manufacturer provides a twelve month limited warranty covering manufacturing defects and workmanship. Other warranties may be provided on a case by case basis.
Affect on Engine Warranty: (When possible, identify any impact the technology may have on an engine's warranty.)	The engine manufacturer should be contacted to determine the specific impact of the product on an OEM engine warranty. However, the technology is sized to stay within OEM backpressure limitations.
Adverse Impacts: **Environmental:**	There are no known adverse environmental impacts.
Safety:	There are no known adverse safety impacts.
Special Operating Requirements: (e.g. ultra-low sulfur fuel or minimum exhaust temperature, etc...)	230V or 400V electrical service is required.
Current Status: (Is the technology commercially available, or is it still under development? How many engines has the technology been installed on, and how long has the technology been in use?)	The technology is commercially available in Europe and Asia and has been employed on captive fleet vehicles such as fork lifts and front end loaders, stationary and mining engines with total installation base of 3,000. According to the manufacturer, the product will be marketed in the United States as of September 1, 2000.

Item	Response
Other: (e.g. fuel penalty, reduced product life, weight, affect on engine performance, etc...)	The size and weight of actively regenerated DPF's are as follows: **HP** **Diameter** **Length** **Weight** 40 hp 13.8" - 25.7" 7.4" - 10.8" 53 lb - 64 lb 100 hp 12.2" - 14.5" 14.6" - 28.4" 64 lb - 179 lb 275 hp - - - - - - 400 hp 2 @ 13.8" 2 @ 20" 2 @ 86 lb
Impacts of Lower Sulfur Diesel Fuel:	The product can be used with California's existing diesel fuel formulations.
Comments: (Address other issues relevant to the use of this technology, including other advantages / disadvantages of using the technology.)	The product regenerates independently of engine exhaust temperature and is suitable for any size engine working under any duty cycle including long idle or light load conditions.

List of Stationary &/or Portable Applications

Technology Name: Unikat Combifilter

Facility / Operator	Engine Information	Permit / Registration	Number of Applications	Time in Service	PM Emission Limit	PM Emission Test Results
There are no known portable or stationary applications Unikat Combifilter in U.S.	Make: Model: Application: Fuel Type:					
However, a Combifilter system is operational in Welland, Ontario, Canada.	Make: Cummins Model: B5.9 Application: Taylor lift truck Fuel Type: Diesel, unknown S concentration		1	27 Months		

List of Emission Test Results

Technology Name: Unikat Combifilter

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Control Efficiency
Special transient cycle designed for a specific backhoe application.	Emission Research and Measurement Division, Environment Canada[30]	Combifilter Mfg. by Engine Control Systems	Make: Caterpillar Model: 3054DIT Year: 1994 BHP: 84 Application: Backhoe Configuration: Unknown Engine Hours: Unknown Fuel Type: 530 ppm S Diesel Fuel Use: 4.66 kg/hr Exhaust Temp: Unknown	PM NOx CO HC	8.46 g/hr 93.79 g/hr 41.66 g/hr 5.47 g/hr	1.77 g/hr 98.70 g/hr 37.56 g/hr 5.17 g/hr	79% -5% 10% 5%
ISO 8178 C1	AB Svensk Bilprovning	Combifilter with oxidation catalyst Mfg. by Engine Control Systems	Make: Perkins Model: 1004T Year: Unknown BHP: about 44 (for 33.7 kw) Application: Unknown Configuration: Unknown Engine Hours: Unknown Fuel Type: 30 ppm S Diesel Fuel Use: 234-236 g/kwh Exhaust Temp: Unknown	PM NOx CO HC	0.59 g/kwh 13.1 g/kwh 4.71 g/kwh 0.48 g as $CH_{1.85}$/kwh	0.03 g/kwh unk 0.11 g/kwh 0.04 g as $CH_{1.85}$/kwh	95% NA 98% 92%

[30] Study reported in SAE Technical Paper #1999-01-0110 entitled "The Impact of Retrofit Exhaust Control Technologies on Emissions from Heavy-Duty Diesel Construction Equipment."

Method & Type of Test	Source Test Company	Product Information	Engine Information	Pollutant	Baseline Emissions	Emission Rate w/ Controls	Control Efficiency
ISO 8178 C1	AB Svensk Bilprovning	Combifilter with oxidation catalyst Mfg. by Engine Control Systems	Make: Scania Model: Unknown Year: Unknown BHP: 150 (for 114.9 kw) Application: Unknown Configuration: Unknown Engine Hours: Unkown Fuel Type: 30 ppm S Diesel Fuel Use: 223-225 g/kwh Exhaust Temp: Unknown	PM NOx CO HC	0.21 g/kwh 9.65 g/kwh 0.98 g/kwh 0.89 g as $CH_{1.85}$/kwh	0.01 g/kwh 9.68 g/kwh 0.12 g/kwh 0.07 g as $CH_{1.85}$/kwh	95% -0.3% 88% 92%